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Climate change research trends in Tanzania: A bibliometric analysis

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Research enhances the efforts to address climate change through improved understanding of the causes, effects and likely impacts as well as formulation of climate change policies and strategies for adaptation and mitigation measures. A bibliometric analysis was conducted to assess research trends on climate change in Tanzania for the period between 2006 and 2016. Data were extracted using the Publish or Perish programme which uses Google Scholar to retrieve the number of publications, citation counts and related metrics. The study findings show that there were 319 scholarly publications for the 10-year period, giving an average of about 32 publications per year. As the rate of growth of publications increased, the corresponding doubling time decreased. Journal articles were the dominant (56.1%) type of publications. Areas with relatively higher number of articles were "climate change adaptation" (25.2%), "climate change impacts/implications" (23.3%) and "climate variability" (13.8%). Many (68.9%) publications were multiple-authored and the degree of collaboration among scholars was 0.69. The top 10 ranked scholars contributed nearly one third (31%) of the publications. These results suggest that research productivity in the area of climate change in Tanzania is generally low compared to other countries in the world. Concerted efforts are therefore necessary to foster the research on climate change in Tanzania.

Key words: Bibliometrics, climate change, research, publications, Tanzania.

INTRODUCTION

Climate change is a global phenomenon that results from increased concentration of Greenhouse Gases (GHGs) in the atmosphere primarily from industrialization, deforestation and increased use of fossil fuels. These lead to higher temperatures, unreliable rainfalls, unpredictable synchromes and storms as well as rise in

sea level all of which have adverse effects on living organisms and the environment (IPCC, 2007). Climate change has direct and indirect impact on water resources, agriculture, forests and biodiversity, health, infrastructure development, tourism, and livelihoods. Generally, there is no country that does not face the

consequences of climate change, though they may be affected at different levels. Developing countries including Tanzania are more vulnerable to the adverse effects of climate change because majority of their populations depend on climate sensitive natural resources and they have lower adaptive capacities (UNFCCC, 2007). In Tanzania, the impacts of climate change on various socio-economic sectors, environment and livelihoods are already vivid and these impacts threat to undermine and even undo development efforts attained so far (Nindi and Mhando, 2012).

Individual countries and the international community are making efforts to address the causes and impacts of climate change (IPCC, 2014). Several adaptation and mitigation measures are being formulated and enforced in many countries in order to address climate change and associated impacts. Research contributes to the efforts that aim at addressing climate change through increased understanding of the causes, effects and likely impacts of climate change as well as formulation of climate change policies and strategies for adaptation and mitigation measures. Scientific research enables informed decision-making and planning including the ability to measure and predict climate change and the implications of its adverse effects on the economy, society and the environment. Globally, climate change research has grown considerably in the past few years following increased magnitude of climate-related effects (Newton et al., 2005).

Assessment of research productivity in a particular discipline or location is an essential step to understand the strength of research activities, identify priority areas and uncover those areas that are less researched. Bibliometric techniques are used to measure research productivity trends and output. These techniques are concerned with the growth, structure, interrelationship and productivity of scientific disciplines (Hood and Wilson, 2001). Bibliometrics use quantitative analysis and statistics to describe distribution patterns of publications within a given topic, field, institution and country. Major data sources for bibliometric studies include the Web of Science, Scopus and Google Scholar databases. Google Scholar uses Publish or Perish (PoP) programme to retrieve publications, citation counts and associated metrics. Comparative studies (Saad, 2006; Bar-ilan et al., 2012; Harzing and Wal, 2013) indicate that PoP retrieves more publications and citations than Web of Science and Scopus. The PoP software programme provides statistics such as the number of publications, citation counts and indices such as the h-index, g-index, Hc-index and HI-norm index (Harzing and Wal, 2008). The h-index simultaneously measures number of publications and citations of a scholar (Hirsch, 2005). Since the h-index is not influenced by very highly cited papers, Egghe (2006) proposed the g-index which gives more weight to highly cited articles. Sidiropoulos et al. (2007) developed the

Hc-index by adding a weight related to the age of each cited article. Furthermore, the HI-norm index offers a better approximation of the author's impact on the number of citations (Braun et al. 2006).

Understanding climate change research trends in Tanzania could help to establish strategies for improving the volume and quality of research in this field. The results would also help to identify research gaps that climate change studies could focus on in the future. In Tanzania, no bibliometric studies have been carried out to measure productivity and trends in climate change research. The present study therefore, analyses the climate change research productivity trends in Tanzania for the period between 2006 and 2016. The chosen period is based on the fact that serious international and national efforts to combat climate change causes and effects started in mid 2000s following the release of assessment reports by the Intergovernmental Panel on Climate Change (IPCC, 1995; 2001, 2007). Specifically, this study analysed the growth of the climate change scholarly literature, determined authorship collaborations, established the distribution of subject categories on climate change, established citations trends of publications, and analysed individual researchers' productivity.

LITERATURE REVIEW

Some bibliometric studies have been conducted in recent years around the world to measure research trends on climate change. Wang et al. (2014) analysed the global scientific performance in climate change vulnerability in the Web of Science database from 1991 to 2012. Among other issues, the results show that the vulnerability researches on climate change have experienced a rapid growth since 2006, and the publications are distributed in several journals. The cooperation at author level was on the rise, and the most widely focused research topics include health issues in the socioeconomic system, food security and water resource management. Venkatesan et al. (2014) also analysed global research productions on climate change using Web of Science databases for the period between 1999 and 2012. The findings show that there were 94,756 records contributed worldwide with an average of 6,769 articles per year. The Relative Growth Rate (RGR) and Doubling Time of the publications indicate that there was an increasing trend in the research production. More than half of the contributions are collaborative research and over 87% of the publications were journal articles. More than two-thirds (66.47%) of the documents were published in three research areas namely Environmental Sciences and Ecology (29,121), Ecology (18,997) and Meteorology Atmospheric Sciences (14,865).

A worldwide scientometric analysis of climate change

research conducted by Husain and Mushtaq (2015) using the Web of Science database analysed 17,266 publications covering the period between 2009 and 2013. The highest number (4,788) of publications was produced in the year 2013 and the lowest (2,238) was in the year 2009. The highest number of publications was produced by USA followed by England. The most prolific author in the field of climate change was W. Thuiller followed by P. Smith. Journal articles were the most widely used document forms followed by reviews. The prolific journals were 'Climatic Change' and 'Global Change Biology'. The study also assessed the citation patterns including the country's citations, citations of affiliated institutes, and average, self and unique citations received of select years. A more recent bibliometric analysis involved 222,060 papers obtained through Web of Science custom data for the period between 1980 and 2014. The findings show a strong increase of papers with a doubling every 5 to 6 years. Continental biomass related research was the major subfield, closely followed by climate modeling. The Journal of Geophysical Research, the Journal of Climate, the Geophysical Research Letters, and Climatic Change appear at the top positions in terms of the total number of papers published (Haunschild et al., 2016).

Alex and Preedip (2010) mapped the climate change research output of India in five-year period from 2005 to 2009 based on papers abstracted in the Web of Science database. The findings revealed that there were 25,081 publications all over the world; of which Indian subcontinent had published 391 papers in all, and these were published in more than 101 scholarly journals. Another study quantitatively analysed the literature on climate change published from five developing countries namely Argentina, Brazil, China, India and Mexico based on Web of Science for the period between 1991 and 2012. A total of 7,065 records were retrieved for climate change for the studied countries. Country-wise results clearly show that China (4,121 publications) and India (1,147 publications) are the countries that produce the maximum outputs quantitatively. Authorship and collaboration trend was towards multi-authored papers (Saravanan et al., 2014).

In Tanzania, no bibliometric studies have been conducted to provide insights on research patterns and trends in the area of climate change. Research has been conducted on climatic extremes and how they have affected agricultural production and food security in Tanzania (Downing et al., 1997; Kijazi and Reason, 2009; Shemsanga et al., 2010; Tumbo et al., 2010). Most of these studies report that both extreme droughts and floods can occur within one season, and that the frequency and severity of these extreme events is expected to increase. There are also studies on the impacts of climate change on crop production (Mwandosya et al., 1998; Munishi et al., 2010; Rowhani et al., 2011). These have reported a general decline in crop productivity as a result of the changing climate. Other studies focused on climate change adaptations or coping measures mainly in agriculture (Mongi et al., 2009; Lyimo et al., 2010; Kangalawe et al., 2011; Shemdoe et al., 2009).

RESEARCH METHODOLOGY

A bibliometric analysis was conducted to assess the research trends on climate change in Tanzania for the period between 2006 and 2016. The chosen period was based on the fact that, as pointed out earlier, serious efforts to combat climate change causes and effects in Tanzania started in mid 2000s following the release of assessment reports by the Intergovernmental Panel on Climate Change (IPCC, 1995, 2001, 2007). Data were obtained using the PoP software which retrieves data through Google Scholar. Google Scholar is often recommended for bibliometric studies because it covers all scholarly publications that are listed and that are not by many databases (Harzing, 2013). In order to ensure that all retrieved publications are those addressing climate change issues in Tanzania, a search strategy was developed in such a way that only those publications with the words "climate" and "Tanzania" in their titles were retrieved. Search results were carefully refined to ensure that only intended works were captured and duplicates were removed. However, the intended publications were once again re-searched via Google scholar to determine whether they are actually on climate change issues in Tanzania. A total of 357 publications were retrieved, however, 38 were found irrelevant and were removed.

For the purpose of this study, the types of publications considered were peer reviewed journal articles, books, chapters in books, technical reports, theses and dissertations, working papers and articles in conference proceedings. The retrieved metrics were the total number of publications, number of authors for each publication, total citation counts, average citations per paper, average citations per year, h-index, g-index, Hc-index and the HI-norm. The limitation of this study is that PoP only retrieves data that are available on the web. This means that any publications and citations that were not available online could not be retrieved. The PoP software programme also has some limitations including the fact that search by affiliation and subject is not possible. In addition, the comprehensive nature of Google Scholar requires that data retrieved through PoP be thoroughly cleaned manually to remove duplicates and unanticipated publications.

RESULTS AND DISCUSSION

The findings focus of the growth of the climate change literature, collaboration patterns, subject categories citations trends as well as individual researchers' publication productivity.

Publication productivity

The findings in this study indicate that there were 319 scholarly documents on different aspects of climate change in Tanzania for the period of 2006 to 2016. It should be noted however, that these data were collected in February 2016 and hence they do not present a

Table 1. Year-wise publication productivity.

Year	No. of publications	Percent	Cumulative publications	lnN_1	lnN_2	RGR	Mean RGR	Dt	Mean Dt
2006	15	4.7	15		2.71	-		-	
2007	10	3.1	25	2.30	3.22	0.92		0.75	
2008	25	7.8	50	3.22	3.91	0.69		1.00	0.69
2009	25	7.8	75	3.22	4.32	1.10	1.06	0.63	
2010	28	8.8	103	3.33	4.63	1.30		0.53	
2011	38	11.9	141	3.64	4.95	1.31		0.53	
2012	43	13.5	184	3.76	5.21	1.45		0.48	
2013	34	10.7	218	3.53	5.38	1.85		0.37	0.36
2014	43	13.5	261	3.76	5.56	1.80	2.04	0.39	
2015	45	14.1	306	3.81	5.72	1.91		0.36	
2016	13	4.1	319	2.56	5.77	3.21		0.22	
			Mean			**1.41**		**0.48**	

Source: Google scholar, 2016.

complete picture for the year 2016. The Relative Growth Rate (RGR) which is the increase in the number of publications per unit of time was calculated as RGR = $(lnN_2 - lnN_1) / (t_2 - t_1)$ where N2 and N1 are the cumulative number of publications in the years t_2 and t_1. The study findings in Table 1 indicate that RGR had increased from 0.92 (2006) to 3.21 (2016) with some fluctuations in the years in-between. Similarly, the mean RGR for the block periods of five years increased from 1.06 (2007 - 2011) to 2.04 (2012 - 2016).

The doubling time which is the period of time required for publications to become double of the existing quantity is directly related to RGR in that if the number of articles doubles during a given period then the difference between the logarithms of numbers at the beginning and end of this period has a value of 693. Thus the corresponding doubling time is calculated as Dt = 0.693/RGR (Mahapatra, 1994). The findings show a decreasing trend from 0.75 (2006) to 0.22 (2016) with some fluctuations in the years in-between. The mean Dt for the block periods of five years decreased from 0.69 (2007 - 2011) to 0.36 (2012 - 2016). The whole study period records the mean RGR and Dt of 1.41 and 0.48 respectively; meaning that as the rate of growth of publications increased, the corresponding doubling time decreased. This shows that the number of publications in the area of climate change in Tanzania had increased over the period of 10 years. However, the total number of publications in climate change research in Tanzania was generally low as compared to the statistics reported in other countries such as China (4,121 publications) and India (1,147 publications) (Saravanan et al., 2014). This suggests that although climate change has become a topical area in the past few years, it has not gained wide attention among scholars in the country. The research productivity is low perhaps because of the recent nature

of the research topic itself and inadequate financial resources to carry out research activities.

The findings in Figure 1 show that majority of literature has been published in the form of journal articles (56.1%) followed at a distant by technical reports (18.5%) and articles in conference proceedings (12.9%). Other publications were theses and dissertations (6.0%), working papers (5.0%), book chapters (1.3%) and books (0.3%). This was expected because most scholarly articles are often published in journals.

Distribution of subject categories on climate change research

The retrieved publications were grouped into 15 different subject categories. A quarter (25.2%) of the publications was on "climate change adaptation" followed by those on "climate change impacts/implications" (23.3%) and "climate variability" (13.8%). In other words, these three areas occupied nearly two-thirds (62.3%) of all climate change scholarly publications produced in Tanzania for the period of 2006 to 2016 as presented in Table 2.

Joint research

The authorship pattern in the area of climate change in Tanzania during the period of 2006 to 2016 shows a joint research trend. Only 99 (31%) publications have been produced by single authors and the rest (68.9%) have been jointly authored by two or more authors as shown in Table 3. The average number of authors per paper was 2.61. The degree of collaboration among scholars in the area of climate change computed as the ratio of the total number of collaborative publications (Nm) to the total
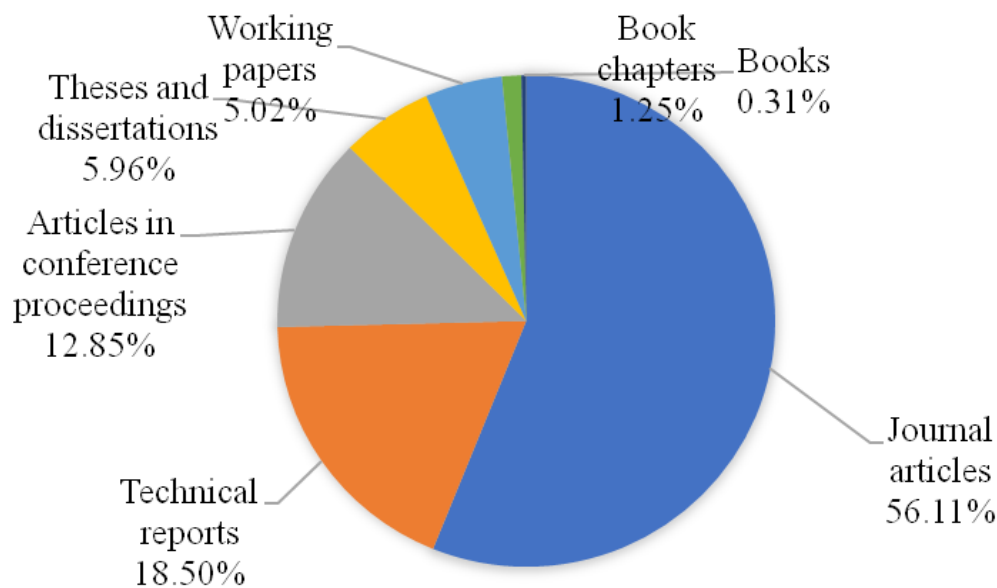
Figure 1. Publication distributions by type.

Table 2. Distribution of subject categories on climate change research.

S/N	Subject category	Frequency	Percent
1	Climate change adaptation	82	25.2
2	Climate change impacts/implications	76	23.3
3	Climate variability	45	13.8
4	Climate change mitigation	31	9.5
5	Climate change vulnerability	28	8.6
6	Climate change effects	14	4.3
7	Economics of climate change	7	2.1
8	Climate change finance	7	2.1
9	Climate extremes	7	2.1
10	Climate resilience	7	2.1
11	Climate volatility	6	1.8
12	Climate scenarios	6	1.8
13	Climate change projections/prediction	5	1.5
14	Seasonal forecasts	3	0.9
15	Climate change awareness	2	0.6
	Total	**326***	**100.00**

*The total output is more than the actual output as some publications addressed more than one sub-discipline.

number of multi-authored publications plus the number of single-authored (Ns) publications (that is, $C = Nm/Nm + Ns$) (Subramanyan, 1983) was 0.69. This indicates a relatively high degree of teamwork in climate change research. This might be due to the fact that research in climate change is multidisciplinary in nature which calls for researchers from diverse fields to share their expertise. However, when a number of authors collaborate on a particular article, the actual contribution of each scholar is difficult to determine.

Indices for all publications

The h-index of the retrieved publications was 19 which means that the authors' 19 publications had been cited

Table 3. Joint research patterns in climate change.

Authorship pattern	No. of publications	Percentage
Single authored publications	99	31.0
Publications with 2 authors	69	21.6
Publications with 3 authors	52	16.3
Publications with 4 authors	53	16.6
Publications with 5 authors	37	11.6
Publications with 6 or more authors	9	2.8
Total	**319**	**100.0**

Table 4. Average indices for all publications.

Metrics	Statistics
h-index	19
g-index	34
hc-index	19
hI, norm	13
hI, annual	1.30
hm-index	13.95

19 or more times each, and the rest of the publications had fewer than 19 citations. When more weight is given to his/her highly cited publications, the g-index was 34 and when more weight is given to newly published works, the hc-index is 19. The hI norm-index which evaluates the effects of co-authorship and estimates the "per author impact" was 13. The hI, annual which is an indicator of an individual's average annual research impact 1.30 (Table 4).

Citation pattern of the research output

Citation analysis measures the impact of each article by counting the number of times they were cited in other articles. High levels of citations to a scientific publication are interpreted as signs of scientific influence, impact and visibility. The citation status of Tanzanian publications on climate change reveals that over half (179; 56.1%) of the publications were cited at least once. These 179 publications were cited 1676 times at the rate of 5.14 average citations per publication and 167.60 cites per year. The top 10 highly cited publications contributed over one third (622; 37.1%) of the total citation counts. The most cited article is titled "Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania" published in Environmental Science and Policy in 2008 with 26 cites/year. This is followed by an article titled "Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania:

The case of Manyoni District in Singida Region, Tanzania" published in African Journal of Environmental Science and Technology in 2008 which had 22.2 cites per year (Table 5).

Table 6 lists the top 10 most prolific authors on climate change in Tanzania during the ten-year period. These 10 most productive authors contributed nearly 37% of the total publications with an average of 12 publications per author. Of these seven most productive authors, six (P. Z. Yanda, R. Y. M. Kangalawe, A. E. Majule, E. T. Liwenga, A. Mascarenhas and J. G. Lyimo) are affiliated to the University of Dar-es-Salaam and two (S. D. Tumbo and P. K. T. Munishi) to the Sokoine University of Agriculture. In other words, these two institutions (that is, University of Dar es Salaam and Sokoine University of Agriculture) had contributed the most in the climate change research in Tanzania.

CONCLUSION AND RECOMMENDATIONS

The present study analysed the climate change research output in Tanzania for the period between 2006 and 2016 using bibliometric techniques. The results have demonstrated a predictable growth of climate change literature in the country, although the total number of publications was generally low despite the fact that climate change has been a topical area for over ten years. Most literature on climate change in Tanzania was contributed by scholars from the University of Dar-es-Salaam and Sokoine University of Agriculture and the larger proportion was in the form of journal articles. The most research areas were "climate change adaptation", "climate change impacts/implications" and "climate variability". There was a good level of team spirit with many publications having multiple authors. Indices such as h-index were generally low indicating the low level of research output and its impact. A good number of publications had been cited by other scientists.

Given the growing incidence of the phenomenon, it is necessary to enhance research on climate change in Tanzania. Research institutions, funding agencies and

Table 5. Highly cited publications.

S/No	Publication's bibliographic details	Citation count	Cites/year
1	Pavavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. Environmental Science and Policy, 11 (7):642–654	208	26.0
2	Rowhani, P., Lobell, D. B., Linderman, M. and Ramankutty, N. (2011). Climate variability and crop production in Tanzania. Agricultural and Forest Meteorology, 151 (4):449-460.	111	22.2
3	Lema, M. A. and Majule, A. E. (2009). Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. African Journal of Environmental Science and Technology, 3 (8):206-218.	95	13.6
4	Ahmed, S. A., Diffenbaugh, N. S., Hertel, T. W., Lobell, D. B., Ramankutty, N., Rios, A. R. and Rowhani, P. (2011). Climate volatility and poverty vulnerability in Tanzania. Global Environmental Change, 21(1):46-55.	51	10.2
5	Mongi, H., Majule, A. E. and Lyimo, J. G. (2010). Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania. African Journal of Environmental Science and Technology, 4 (6): 371-381.	54	9.0
6	Tacoli, C., 2011. Not only climate change: mobility, vulnerability and socio-economic transformations in environmentally fragile areas in Bolivia, Senegal and Tanzania (No. 28). IIED.	43	8.6
7	Zahabu, E. (2008). Sinks and sources: a strategy to involve forest communities in Tanzania in global climate policy. Doctoral thesis. University of Twente.	50	8.3
8	Nelson, V. and Stathers, T., 2009. Resilience, power, culture, and climate: a case study from semi-arid Tanzania, and new research directions. Gender & Development, 17(1):81-94.	53	7.6
	Jones, A.E., Wort, U.U., Morse, A.P., Hastings, I.M. and Gagnon, A.S., 2007. Climate prediction of El Niño malaria epidemics in north-west Tanzania. Malaria Journal, 6(1), p.1.	40	4.4
9	Jonsson, P., Bennet, C., Eliasson, I. and Lindgren, E.S., 2004. Suspended particulate matter and its relations to the urban climate in Dar es Salaam, Tanzania. Atmospheric Environment, 38(25), pp.4175-4181.	47	3.9

Table 6. Most productive authors in the area of climate change.

S/N	Authors	No. of publication
1	P. Z. Yanda	19
2	R. Y. M. Kangalawe	18
3	S. D. Tumbo	17
4	P. K. T. Munishi	13
5	A. E. Majule	12
6	E. T. Liwenga	10
7	J. G. Lyimo	10
8	R. S. Shemdoe	7
9	A. Mascarenhas	6
10	A. S. Kebede	6
Total		**118**

the government should make concerted efforts to foster the research on climate change. The main limitation of this study is its focus on publications and citations that were available online and those that had "climate" and

"Tanzania" as keywords in their titles. This means that publications and citations that were not available on the web were not retrieved.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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