Original Article

A decade of the Blue Economy concept in the western Indian Ocean region: research and technology perspectives

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Abstract

The World Bank defines the Blue Economy as "the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of the ocean ecosystem". The implementation of Blue Economy concept at global, continental, regional and country levels have had mixed results since its origin in 2012. Here, a systematic review of progress in the western Indian Ocean region is undertaken, focused on research and technology between 2012 and 2021. Apart from applications to ocean modelling, big data and satellite data, the term Blue Economy did not appear as a key term in most publications from the region, suggesting that it is not well understood or researched. Existing studies aligned with three Africa Blue Economy Strategy thematic areas: (1st) fisheries, aquaculture and ecosystem conservation; (3rd) environmental sustainability, climate change and coastal infrastructure; and (5th) policies, institutional and governance. Multi-disciplinary and multi-institutional collaborations focusing on technology are required to boost Blue Economy implementation in the Western Indian Ocean region, including for thematic areas for shipping transportation and trade (2nd) and sustainable energy, extractive minerals, gas, and innovative industries (4th).

Keywords: Blue Economy, ocean economy, ocean model, satellite data, western Indian Ocean, Africa Blue Economy Strategy

Introduction

The concept of the Blue Economy originated from the United Nations Conference for Sustainable Development held in Rio de Janeiro in Brazil in 2012 (UNCTAD, 2014). Although the concept is interchangeably referred as "Ocean Economy" or "Marine Economy", the term "Blue Economy" is currently widely used at international, regional and national levels. It is considered as the mid-neutral factor to resolve the two long term competing/conflicting discourses around opportunities of growth and development through ocean resources, and protection of the healthy ocean ecosystems threatened by socio-economic activities (Voyer *et al*., 2018). The United Nations concept paper defined the Blue Economy as an ocean economy that aims at "the improvement of human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UN, 2014). In 2017, the World Bank provided a comprehensive definition of the Blue Economy as "the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem" (World Bank, 2017). This definition was further emphasized in World Bank (2020).

Growth and development using ocean-based economic activities conflicts with the balance of the long-term capacity and protection of the health of ocean

ecosystems to support the activities in a sustainable manner. Human activities are responsible for about 80 % of ocean pollution through dumping waste products including sewage, pesticides, industrial chemicals, and other solid waste, as well as through climate change, other forms of environment pollution, unsustainable fishing and unregulated coastal development (WWF, 2014; Tirumala and Tiwari, 2022). The Blue Economy is further defined as a "practical ocean-based economic model using green infrastructure and technologies, innovative financing mechanisms, and proactive institutional arrangements for meeting the twin goals of protecting our oceans and coasts, and enhancing their potential contribution to sustainable development, including improving human well-being, and reducing environmental risks and ecological scarcities" (PEMSEA, 2012; Tirumala and Tiwari, 2022). Therefore, the Blue Economy posits the inherent conflicts of ocean activities for economy and protection of the health of ocean ecosystems to support the activities in a sustainable manner.

Since the introduction of the Blue Economy concept in 2012, different studies have been conducted mainly with a focus at global and continental levels to achieve different objectives. For example, Lee *et al*. (2021) described the Blue Economy and the total environment through mapping the interface between the two, and Tirumala and Tiwari (2022) reported fewer financial flows for Blue Economy projects as compared to others types of investments. Furthermore, Lee *et al*. (2020) compared the scope and boundaries as well as the key stakeholders and their interests and roles between the Blue Economy and the United Nations Sustainable Development Goals (UN SDGs) which were launched by the United Nations General Assembly (2015). Lee *et al*. (2020) found that the Blue Economy is highly associated with SDGs 14-17 although most stakeholders with direct or indirect involvement in the Blue Economy prefer to associate Blue Economy with SDG 3-Good health and well-being, and SDG 8-Decent work and economic growth.

At continental level, the Africa Blue Economy Strategy as narrated by Sacko (2020) indicates five critical blue economy sectors, considered as thematic areas including: a) fisheries, aquaculture and ecosystem conservation; b) shipping transportation and trade; c) sustainable energy, extractive minerals, gas, and innovative industries; d) environmental sustainability, climate change and coastal infrastructure; and e) policies, institutional and governance (https://www.au-ibar.org/strategy-documents). These critical thematic areas for the Blue Economy in Africa are considered to play significant roles for socio-economic development in different countries and should be of high priority for scientific research. The current development in computing (numerical modelling) in conjunction with the theories, observations and satellite data in the Blue Economy research field helps to avoid difficulties associated with each approach when used separately. Consequently, a better understanding of different aspects/factors related to the Blue Economy can be achieved, including perspectives in research and applied technology on this important topic, which is the subject of this study.

Blue Economy contribution and management approaches

The Blue Economy concept emphasizes the importance of embracing the opportunities related to economic activities from ocean resources and environments while recognizing and addressing ocean threats in order to preserve healthy ocean ecosystems in a sustainable manner. The contribution of the coastal and marine resources and related industries to the market value is estimated as USD 3 to 5 trillion making up about 5 % of the global Gross Domestic Product (GDP) (UN, 2015) and 15 %–20 % of GDP in some East Asian countries (Pauli, 2010).

The estimation of annual value generation in 2018 for the Africa Blue Economy sectors was USD 296 billion with 49 million jobs (AU-IBAR, 2019; Sacko, 2020). Such contribution to the African continent involves USD 80 billion from offshore oil and gas exploration, USD 80 billion with 24 million jobs from the tourism sectors, and about 3 % of the global shipping value with about 500 million tonnes of goods handled through the African harbours. Furthermore, fishing contributes to about USD 15 billion with about 13 million employees where the marine capture fisheries product is about 10 million tonnes providing food and nutritional security to 200 million Africans, contributing about 20 % or more of the animal protein consumed in Africa (AU-IBAR, 2019; Sacko, 2020). However, Agnew *et al*. (2009) reported that the illegal catch of seafood in world was at least 20 % leading to losses of about US$ 10 and $ 23 billion per year.

In Tanzania, Jiddawi and Öhman (2002) reported fishing as the main food source and commercial activity in the coastal communities which contribute about

2.1-5.0 % to the country's gross domestic product for mainland Tanzania and about 2.2-10.4 % for Zanzibar. Manyilizu *et al*. (2014; 2016) pointed out the recent discoveries of offshore oil and gas near Mtwara on the southern Tanzanian shelf are expected to boost the country's economy substantially. Moreover, marine and coastal shipping through the four major ports of Dar es Salaam, Zanzibar, Tanga and Mtwara, contributes significantly to the country's trade and income. These ports provide transport services to local communities as well as transit goods to land-locked countries such as Uganda, Rwanda, Burundi, Democratic Republic of Congo, Zambia and Malawi. The aforementioned socio-economic activities fall in the Blue Economy concept and involve formal planning and managing of marine fisheries, ecosystems and shipping as well as oil and gas extraction in the region.

There are different instruments and institutions supporting sustainable development of the Blue Economy from a global scale to national levels. The UN SDGs, endorsed by all member states in 2015, advocate potential solutions regarding the Blue Economy at the global level. The notable endorsement is through SDG-14-Life below water for conserving and sustainably use the oceans, seas and marine resources for sustainable development by 2030. The United Nations (UN) declared 2021-2030 as the "Decade of Ocean Science for Sustainable Development" to support efforts to reverse the cycle of the decline in ocean health and gather ocean stakeholders worldwide behind a common framework. Such a framework is aimed to ensure ocean science can fully support countries in creating improved conditions for sustainable development of the ocean.

The African Union Agenda 2063, the Africa we want, goal number 7 calls for accelerated economic growth of marine resources, renewable energy, ports operations and marine transport. This agenda is in line with the Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa (PFRS) as stated in AUC-NPCA (2014), the 2050 African Integrated Maritime Strategy (AIMS 2050) published in African Union (2012), Lome Charter on maritime security and safety and development in Africa 2016, the Africa Blue Economy Strategy launched in February 2020, and is supported by eight Regional Economic Communities (RECs), Regional Fisheries Bodies and Regional Seas Programmes. All these programmes support Blue Economy research and applications at the continental and regional levels in line with the Blue Economy Strategy as narrated by Sacko (2020), with the five critical blue economy sectors which are considered as thematic areas. Thus, this study focuses on studying the Blue Economy concept in the context of research and the corresponding technology used in research in the countries of the Western Indian Ocean (WIO) region.

Research gaps

The five critical thematic areas for the Blue Economy in Africa are considered to play significant roles for socio-economic development in different countries and should be earmarked as high priority in scientific research.

The roles of research and development (R&D) as well as technology for the Blue Economy related studies should be addressed at regional and country levels. Furthermore, technologies applied to the Blue Economy concept like satellite and big data as well as modelling have not been given strong attention in research. The information technology stakeholders working to support Blue Economy studies appear to have be overlooked in previous analyses. Thus, this study applies a systematic review after a decade of the Blue Economy concept in the western Indian Ocean region in relation to research and technology from 2012 to 2021. The study is guided with the five critical blue economy sectors which are considered as thematic areas from Africa Blue Economy Strategy as narrated by Sacko (2020). The study aims at addressing the following specific research questions:

- To what extent has the Blue Economy concept been associated with research conducted in the WIO from 2012 to 2021 based on the thematic areas of the African Blue Economy Strategy?
- What has the involvement been of each country in research on the Blue Economy concept in the WIO in terms of institutions and authors from 2012 to 2021?
- What technology has been used in research related to the Blue Economy concept in the WIO from 2012 to 2021?

Addressing these research questions provides insight into the Blue Economy concept in the region in order to assist researchers and policy makers in their work in this field.

Materials and Methods

Study area

This study applies a systematic review of a decade of the Blue Economy concept in the WIO with regard to research and technology from 2012 to 2021. The Western Indian Ocean Marine Science Association (WIOMSA) is a leading non-governmental organization promoting science and research in the WIO. The WIOMSA was established as a regional, non-profit, membership organization in 1993 and registered in Zanzibar, Tanzania in 1994 (https://www.wiomsa.org/).The WIOMSA focuses on supporting and promoting the educational, scientific and technological development of all aspects of marine sciences in the WIO region which includes 10 countries: Somalia, Kenya, Tanzania, Mozambique, South Africa, Comoros, Madagascar, Seychelles, Mauritius, Réunion (France).

In the region, the organization is interested in connecting research skills and knowledge generated from marine and coastal ecosystems in the region with management and governance issues (https://www.wiomsa.org/). The WIOMSA has managed to promote different activities regarding marine and coastal ecosystems in the region. Since its establishment, the number of members has significant increased especially from 1999 to 2014. Furthermore, the organization has broadened the scope of research in the region by supporting multidisciplinary, interdisciplinary and transdisciplinary (MIT) research approaches in order to have significant impacts to the communities. Previously, the focus was on natural science only while nowadays the organization supports work on ocean governance, accounting and social sciences in the region.

In order to accelerate research in the region, the organization provides grants for research and conference/training participation for members in the region. Furthermore, the organization has launched its own symposium with the 12th WIOMSA Scientific Symposium held in October 2022 in Nelson Mandela Bay in South Africa, as well as the Western Indian Ocean Journal of Marine Science (WIOJMS). Both the symposium and the journal facilitate disseminate of research in the region and bring together different stakeholders in the field of marine and ocean sciences. The scope of this study includes the 10 countries in the WIO and extensive review of the publications in the WIOJMS has been undertaken.

Research dataset and identification of literature

The WIOMSA is well recognized as an organization which promotes and supports research activities in the WIO through different approaches. As mentioned, this study was based on research published in the WIOJMS with Journal Identifiers eISSN: 0856-860X, print ISSN: 0856-860X. It should be noted that the analysis does not include research that may have been conducted in the WIO but has been published in other journals besides the WIOJMS.

The WIOJMS provides an avenue for the wide dissemination of high-quality research generated in the region targeting the sustainable use of coastal and marine resources. It deals with original research articles in all aspects of marine science and coastal management. The journal mainly focuses on topics including, but are not limited to theoretical and empirical studies in oceanography, marine biogeochemistry, legal and institutional frameworks as well as interactions/relationships between humans and the marine environment.

The journal features state-of-the-art review articles and short communications with special issues on major events or important thematic issues. It is noteworthy that the submitted articles are subjected to standard peer-review prior to publication (https://www.ajol. info/index.php/wiojms/index).

Data analysis

The database of journal articles from the WIOJMS was analyzed for 10 years from 2012 to 2021. Network analysis has evolved as a methodology for the study of social structure using VOSviewer version 1.6.18. The most significant feature of network analysis is the use of relational data.

The people, organizations, and objects that form a network are referred to as nodes, and a network structure is that which expresses the position and relation between nodes (Scott, 2012). For network analysis, it is important to determine the nodes and links of the network. Here, community analysis is an analysis that detects the community structure at the substructure level of the network. A community structure in a network is a subgroup (community or module) in which the relationships among specific nodes (local communities) are dense internally but not externally (i.e., with other communities) (Newman, 2010).

In the analysis, the meaning of the community structure is the identification of conceptual groups that form

a contextual cluster (Paranyushkin, 2011). VOSviewer calculates the community, or cluster, based on modularity (Newman and Girvan, 2004). VOSviewer also improves the accuracy by adding a smart local moving algorithm (Waltman and van Eck, 2013), and adjusts the number of clusters by adjusting the resolution parameter γ in the Modularity function (Yan *et al*., 2012).

The analysis of the WIOJMS database involved articles from 2012 to 2021 using VOSviewer software to create a co-occurrence map based on text data downloaded through API Crossref through Search Query searching. About 85 journal articles were retrieved to which co-occurrence terms in title and abstract fields were extracted with conditions of ignoring structured abstract labels and copyright statements. Basing on the threshold with the minimum number of occurrences of term 10 of the total 2583 terms, 33 terms met the threshold and were selected for analysis. Statistical descriptions were used to evaluate trends in temporal growth, and geographical and national interests in the Blue Economy literature. Bibliometric analyses based on keywords conducted in VOSviewer software (Van Eck and Waltman, 2014) were employed to scrutinize interrelations and patterns of knowledge production. Co-occurrence analysis was employed to analyze networks in respect of the intellectual structure and terminological interrelation that have evolved in this knowledge base (Udomsap and Hallinger, 2020).

Furthermore, the analysis of the WIOJMS database involves journal articles from 2012 to 2021 using VOSviewer software to create a co-occurrence map based on bibliographic data for authors downloaded through API Crossref through Search Query searching. About 85 journal articles with 252 authors were retrieved based on counting their main authorships with a minimum of two documents for an author. About 52 authors were calculated according to the total strength of the co-authorship links with other authors. However, some of the items in the network were not connected to each other; thus, the largest set of connected items consists of 23 items which were considered to show the set of items instead of all. Statistical descriptions were used to evaluate trends in temporal growth, geographical and national interests in the Blue Economy literature. Bibliometric analyses based on authors conducted in VOSviewer software (Van Eck and Waltman, 2014) were employed to scrutinize interrelation and patterns of knowledge production. Co-occurrence analysis was employed to analyse networks in respect of the intellectual structure and terminological interrelation, that have evolved in this knowledge base (Udomsap and Hallinger, 2020). To visualize a network, the relatively different size of each node-assigned keyword expressed that keyword in a bigger node and indicated it occurred across the whole network as compared to the smaller sized ones. Link strength was expressed as the relative width of the line in the network structure. Altogether, occurrences, link strength to the Blue Economy, and total link strength of keywords were analysed and organized using cluster analysis.

Results and Discussion

The results and discussion of this research focuses on systematic research of key terms and key authors in the research conducted in the WIO region. Furthermore, the extent to which technology has been utilized in the regional research is presented. Generally, the term Blue Economy did not appear in the majority of the studies conducted in the region. Thus, the study considers terms related to the five thematic areas identified by the Africa Blue Economy Strategy as reference to the Blue Economy concept. As mentioned above, the thematic areas are 1) fisheries, aquaculture and ecosystem conservation; 2) shipping transportation and trade; 3) sustainable energy, extractive minerals, gas, and innovative industries; 4) environmental sustainability, climate change and coastal infrastructure; and 5) policies, institutional and governance (https://www.au-ibar.org/strategy-documents).

Blue Economy vs key research terms

Density visualization of the keywords in the study are portrayed in Figure 1. Basing on the five thematic areas of the African Blue Economy Strategy, the keywords appeared to relate to the first, fourth and fifth thematic areas of fisheries, aquaculture and ecosystem conservation; environmental sustainability, climate change and coastal infrastructure; and policies, institutional and governance, respectively. However, no key term appeared to be associated with the second and third thematic areas of shipping transportation and trade; and sustainable energy, extractive minerals, gas, and innovative industries, respectively.

The first thematic area on fisheries, aquaculture and ecosystem conservation relates to key terms including species, fishery, fish, habitat, catch, mangrove, *S. commersonnii*, and fishing area. In this thematic area, the term species appeared to be the central key term among the other key terms in the largest cluster with about 81 frequencies. This finding suggests that much

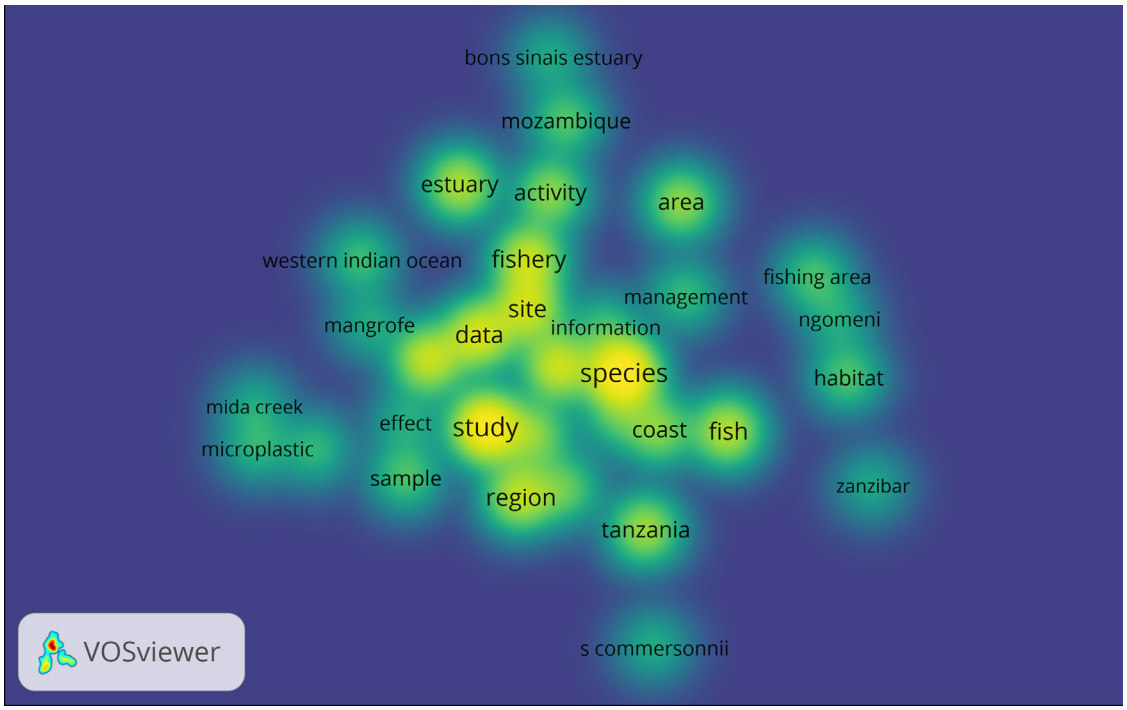

Figure 1. Density visualization of research keywords for publications on the Blue Economy concept in the western Indian Ocean region.

of the research focused on species and that the majority of the research focused on marine biology.

The fourth thematic area of environmental sustainability, climate change and coastal infrastructure is reflected by the key terms water, estuary, activity, coast, western Indian Ocean, Kenyan coast, microplastic, community, and Bons Sinais Estuary. The keyword water appeared very frequently on about 44 occasions. The key terms in this thematic area include microplastics, as a ocean/sea pollutant. Furthermore, the term community which could be associated with coastal infrastructure in the region appeared in this thematic area.

The fifth thematic area which is about policies, institutional and governance is reflected by the terms data, study, site, area, sample, year, region, information, effect, management, Mida Creek, Ngomeni, Zanzibar, Kenya, Mozambique, and Tanzania. In this thematic area, the terms study, data, site and Kenya appeared more frequency with 75, 49, 45 and 45 occurrences, respectively. This suggests that many of the studies might have focused on Kenya. Moreover, terms like Zanzibar, Tanzania, and Mozambique indicate their coverage in studies related to the Blue Economy in the region.

To understand links and clusters among the key terms in the study, a network analysis diagram with different colours was created (Fig. 2). In VOSviewer, creation of a network picture (also known as Label view) circles or labels important items (in this case, key terms with many simultaneous links) which appear large. In Figure 2, the link strength, which calculates the distance between nodes, is extracted by the full counting method. As the similarity of the items increases, the distances appear closer, but the minimum distances are maintained to prevent complete overlap (Van Eck and Waltman, 2010).

Cluster 1 (in red) consists of the eight key terms of activity, community, data, management, mangrove, region, study and year reflecting the fourth thematic area relating to environmental sustainability, climate change and coastal infrastructure and the fifth thematic area for policies, institutional and governance from the Africa Blue Economy Strategy.

Cluster 2 (in green) consists of the seven key terms of area, catch, coast, fishing area, Kenya, Ngomeni and species reflecting the first thematic area for fisheries, aquaculture and ecosystem conservation, the fourth thematic area environmental sustainability, climate change and coastal infrastructure, and the fifth thematic area for policies, institutional and governance .

Cluster 3 (in blue) consists of the six keywords of effect, Kenyan coast, microplastic, Mida Creek, sample and water reflecting the fourth thematic area environmental

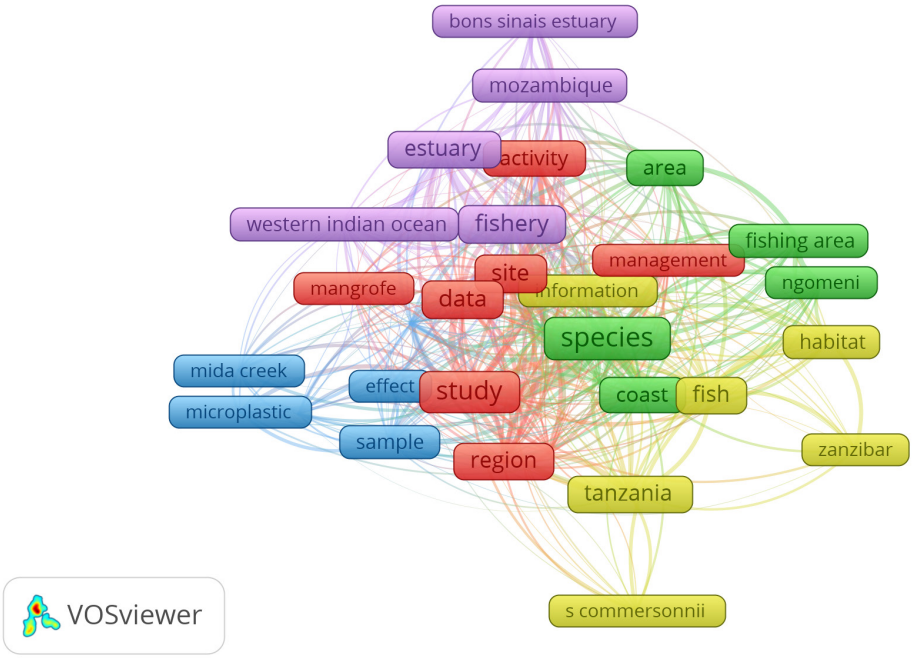

Figure 2. Network visualization of research key words for publications on the Blue Economy concept in the western Indian Ocean region.

sustainability, climate change and coastal infrastructure, and the fifth thematic area for policies, institutional and governance from the Africa Blue Economy Strategy.

Cluster 4 (in yellow) consists of the six keywords of fish, habitat, information, *S. commersonnii*, Tanzania and Zanzibar reflecting the first thematic area for fisheries, aquaculture and ecosystem conservation, and fifth thematic area for policies, institutional and governance from the Africa Blue Economy Strategy.

Cluster *5* (in blue) consists of the 10 keywords of Bons Sinais Estuary, estuary, fishery, Mozambique, Western Indian Ocean fish, habitat, information, *S commersonnii*, Tanzania and Zanzibar reflecting the first thematic area for fisheries, aquaculture and ecosystem

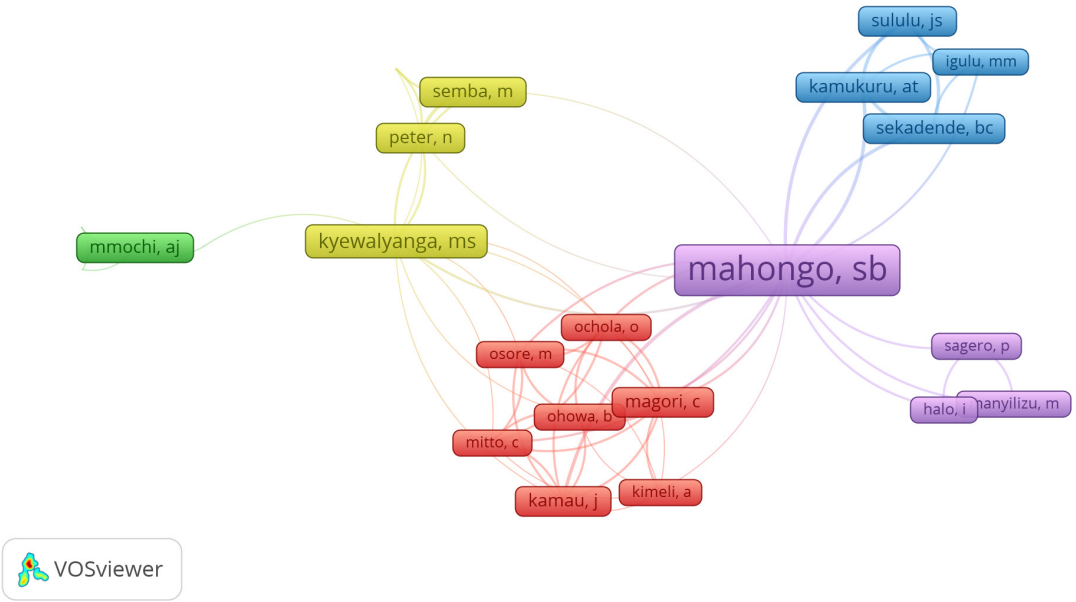

Figure 3. Authorship network visualization for publications on the Blue Economy concept in the western Indian Ocean region.

conservation, and the fourth thematic area environmental sustainability, climate change and coastal infrastructure. Moreover, the cluster indicates the fifth thematic area for policies, institutional and governance from Africa Blue Economy Strategy.

Blue Economy vs researchers and institutions

Five clusters of research authors were formed from the network analysis diagram with different colours (Fig. 3). Also in Figure 3, the link strength, which calculates the distance between nodes, was extracted by the full counting method. As the similarity of the items increases, the distances appear closer, but the minimum distances are maintained to prevent complete overlap (Van Eck and Waltman, 2010).

Cluster 1 (in red) consists of the seven authors J. Kamau, A. Kimeli, C. Magori, O. Ochola, B. Ohowa and M. Osore and Cluster 2 (in green) consists of the four authors N.S. Jiddawi, A.J. Mmochi, M.S. Mtolera and S.A. Yahya. Both these clusters focus mainly on the first thematic area for fisheries, aquaculture and ecosystem conservation.

Cluster 3 (in blue) consists of the four authors M.M. Igulu, A., Kamukuru, B.C. Sekadende and J.S. Sululu addressing the first thematic area for fisheries, aquaculture and ecosystem conservation in conjunction with the fifth thematic area for policies, institutional and governance from Africa Blue Economy Strategy.

Cluster 4 (in yellow) consists of the four key authors M.S. Kyewalyanga, C. Lugomela, N. Peter and M. Semba reflecting the first thematic area for fisheries, aquaculture and ecosystem conservation, and the fifth thematic area for policies, institutional and governance.

Cluster 5 (in blue) consists of the four arthors I. Halo, S.B. Mahongo, M. Manyilizu and P. Sagero reflecting the fourth thematic area environmental sustainability, climate change and coastal infrastructure, and fifth thematic area for policies, institutional and governance. S.B. Mahongo appeared the most in all clusters (11 documents and 35 total link strength).

In order to gain insights into the instruments and institutions supporting research in the WIO the authors'

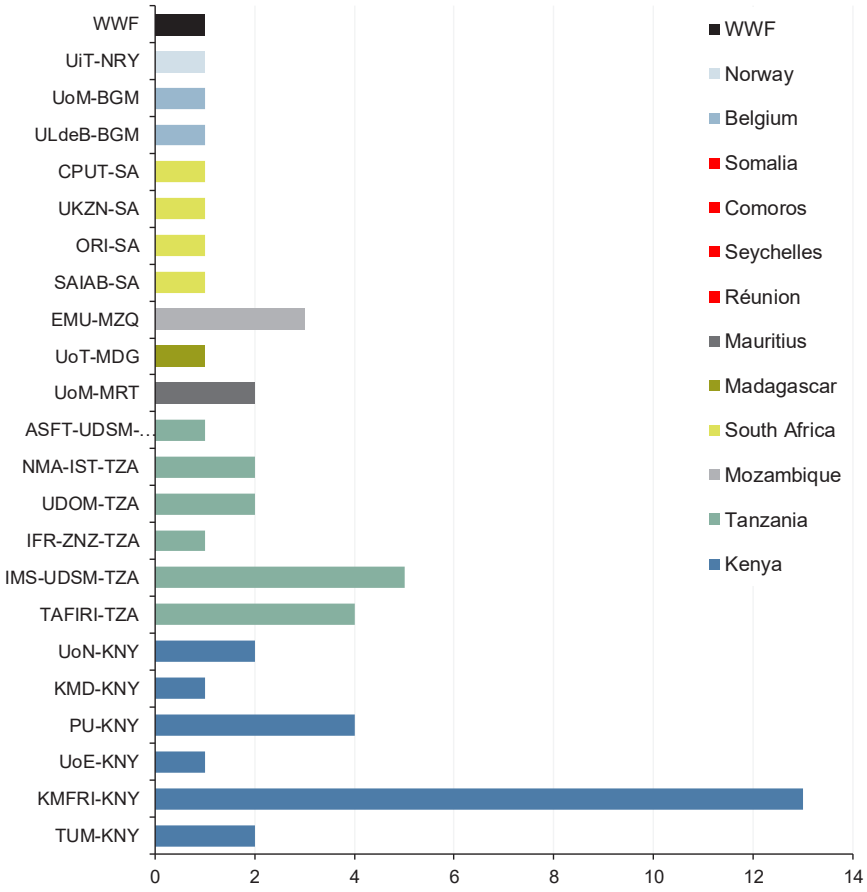

Figure 4. Number of authors per institution per country for publications on the Blue Economy concept in the western Indian Ocean region.

affiliations and their respective countries were considered (Fig. 4). Kenya appears to have had six active research institutions from 2012 to 2021 with the Kenya Marine and Fisheries Research Institute (KMFIRi) having the highest number of authors, with about 13 active researchers. The other institutions were the Technical University of Mombasa (TUM, two authors), University of Eldoret (UoE, one author), Pwani University (PU, four authors), Kenya Meteorological Department (KMD, one author) and the University of Nairobi (UoN, two authors).

In Tanzania, six institutions appeared to have active authors with the Institute of Marine Science at University of Dar es Salaam leading (IMS-UDSM, five authors), followed by the Tanzania Fisheries Research Institute (TAFIRI, four authors). Other active authors came from the Institute of Fisheries Research in Zanzibar (IFR, one author), the University of Dodoma (UDOM, two authors), Nelson Mandela Africa-Institute of Science and Technology (NMA-IST, two authors), and the Aquatic Science and Fisheries Technology Department, University of Dar es Salaam (ASFTD-UDSM, one author).

One, two, and three authors appear from the University of Toliara in Madagascar, the University of Mauritius (UoM) in Mauritius and the Eduardo Mondlane University (EMU) in Mozambique, respectively.

Each of four research institutions in South Africa had one author. These were the Oceanographic Research Institute (ORI), University of KwaZulu-Natal (UKZN), and South African Institute for Aquatic Biodiversity, and Cape Peninsular University of Technology (CPUT). Similarly, one author each appeared for UiT – the Arctic University of Norway, WWF Tanzania office, the Université Libre de Bruxelles, and the University of Mons from Belgium. However, among the ten states of the WIO, the five states of Somalia, Comoros, Madagascar, Seychelles, and Réunion (France) did not appear in the screened documents suggesting either low levels of publication in the WIOJMS or poor research capacity on issues regarding the WIO Blue Economy.

Blue Economy vs technology

Utilization of different technological research approaches by authors in respective countries is depicted

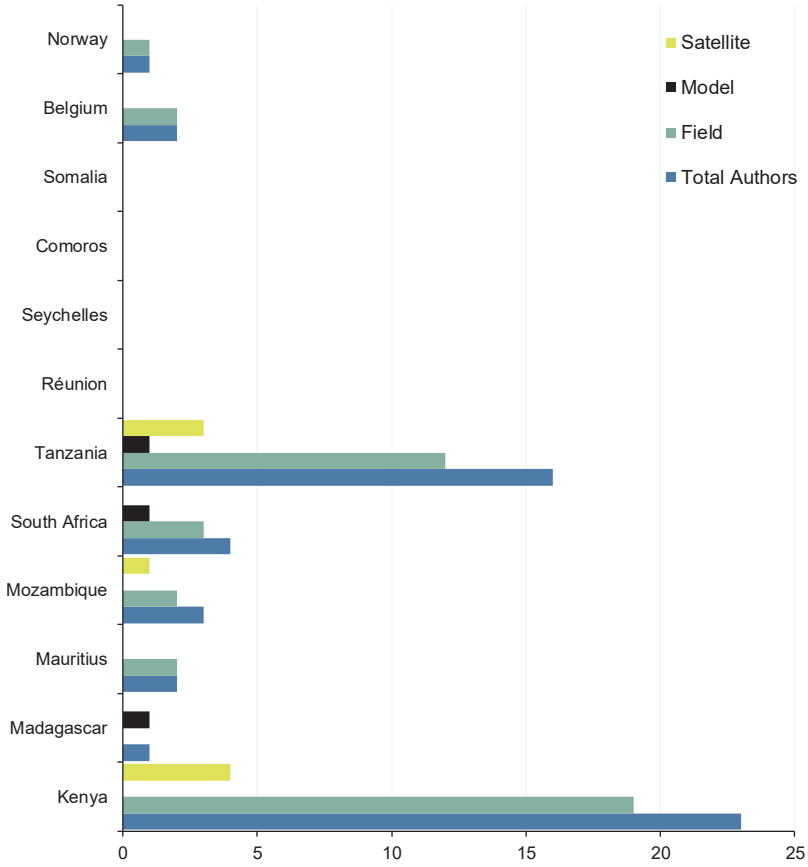

Figure 5. Number of authors per approach used for research and their country for publications on the Blue Economy concept in the western Indian Ocean region.

in Figure 5. The three approaches used in research are field/in-situ, model and satellite modes. The field work approach appeared to dominate in the WIO research and was used by 41 authors (79 % of all authors), and eight authors used satellite and three model approaches. With advances in computing, numerical modelling combines the theories, observations and satellite data into Blue Economy field helping to overcome difficulties associated with each approach when used separately. As a result, a better understanding of ocean dynamics and properties such as sea surface current, sea surface height and sea surface temperature may be achieved.

Of the 23 authors/researchers in Kenya, there were 19 that used the field approach compared to four authors who used satellite data, and none used the model approach. For authors from Mauritius, Mozambique, as well as those from Belgium and Norway most studies focused on in-situ/field approaches involving fisheries, aquaculture and ecosystem conservation. A small number of users of the model and satellite approach appeared in Tanzania (field-16, satellite-3, and model-1). The reasons for such small numbers could be a lack of computing knowledge and/or facilities in the institutions as well as human capacity for these approaches.

Conclusions

The Blue Economy concept has become a popular term used in discussions involving ocean and environmental issues in relation to economic development. The term posits the inherent conflicts of ocean activities for economic development and protection of the health of ocean ecosystems to support the activities in a sustainable manner. This study used a systematic review to analyze a decade of the presence of the Blue Economy concept in the WIO from the perspective of research and technology from 2012 to 2021. It focused on the research and technological perspectives of the Blue Economy concept in the WIO in relation to the five critical blue economy sectors which are considered as thematic areas in the Africa Blue Economy Strategy.

The results indicate that the term Blue Economy does not appear as a key term in most publications in the region, which implies that it is either not well understood or researched. Furthermore, most of the research utilized by authors from Kenyan Institutions use the field approach with no or poor support of technology like models, big data and satellite data. Predominant challenges for ocean modelers are a lack of human capacity, storage capacity, bandwidth and internet connectivity, availability of in-situ data for model evaluation and training/knowledge transfer.

As far as the five thematic areas of the Africa Blue Economy are concerned, it appeared that research has been conducted mainly in the first, fourth and fifth thematic areas of fisheries, aquaculture and ecosystem conservation, environmental sustainability, climate change and coastal infrastructure, and policies, institutional and governance, respectively. However, no key term appeared to be associated with the second and third thematic areas of shipping transportation and trade; and sustainable energy, extractive minerals, gas, and innovative industries, respectively.

Thus, multi-disciplinary and multi-institutional collaborations and management as well as identifying proper technology and its utilization will enhance research in support of Blue Economy development, particularly in all five thematic areas of the Africa Blue Economy Strategy. Ocean science accompanied by innovation and technology should be used in studies to enhance research capacity in the region by supporting multidisciplinary, interdisciplinary and transdisciplinary (MIT) research approaches.

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