Towards ICT-Driven Tanzania Blue Economy: The Role of Higher Learning Institutions in Supporting the Agenda

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Abstract. In different occasions, the President of Tanzania and that of the revolutionary government of Zanzibar have emphasized the importance of Blue Economy in socio-economic development. Inspired by their statements, and noting the reports from previous studies, we argue that sustainable Blue Economy can be achieved through effective utilization of Information and Communication Technology (ICT). This work investigated the contribution of ICT in sustaining the Tanzania Blue Economy. To this end, we have extensively reviewed the curricula of the selected Tanzanian Higher Learning Institutions (HLIs) to investigate ICT programs in such institutions. Results show that approximately 29% of the 24 selected universities lack ICT programs, and the remaining universities contain an inadequate number of ICT programs. This observation further suggests a need to reform the curricula for HLIs by incorporating more ICT programs, especially those directly linked with Blue Economy. In addition, researchers should be encouraged and supported to undertake ICT multidisciplinary research focusing on maximizing the potential benefits of marine and fresh waters while preserving the environment. Our work opens interesting research opportunities on the application of ICT as enabler to foster and sustain Blue Economy. We have established possible research directions in machine learning, data science, and electronics for researchers to seize and advance Blue Economy.

Keywords: Blue Economy · Information and Communication Technology · Higher Learning Institutions

1 Introduction

The effective utilization of Information and Communication Technology (ICT) marks a key determinant for both individual business success and national economic growth. The emergence of the information age, in particular, emphasizes the importance of ICT in facilitating the nation's socio-economic development through education, research

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and innovation. The Tanzania National ICT Policy 2016 [1] and the National Development Vision 2025 [2] acknowledge that the nation can significantly accelerate its socio-economic development and gain global competitiveness through development, utilization, and exploitation of ICT.

For years, the Tanzanian government has been expanding access to social and economic services through transformation of ICT infrastructures. The government has constructed the National Fiber Optic Cable network and the National ICT Broadband Backbone to achieve its grand ICT vision. The backbone infrastructure enhances the usage of computer and mobile ICT applications, including e-government, e-learning, e-health, and e-commerce, and supports research, innovation and future ICT services [1]. The government believes that ICT, if properly exploited, can positively influence productivity, lower prohibitively high operational costs, and promote competitiveness in industries, hence strengthening its economy and increasing employment opportunities [3].

Any country should invest in sustainable exploitation of its natural resources to create medium- and long-term employment opportunities, reduce poverty and improve human wellbeing [4]. The driving force for the Tanzania sustainable transformation can be measured through investment in natural endowment of the country. Tanzania has, in the recent past, been doing well in attracting local and foreign investments. However, the challenge remains to scale up the amount and quality of investments in line with workable economy models [3]. While the Market Economy offers many advantages, such as innovation and entrepreneurial opportunities, it also suffers from inequitable distribution of wealth, poor work conditions, and environmental degradation. Similarly, the Green Economy[1] remained dormant due to innumerable challenges of high production cost, poor technology, employment and business losses, and lack of awareness to the general public. Subsequently, Blue Economy has been identified as a more appropriate technology for sustainable socio-economic development [5].

The Blue Economy, also referred to as the ocean or maritime economy, is a concept that simultaneously encourages social inclusion, environmental sustainability, strengthening of maritime ecosystems, transparent governance as well as economic growth and development [6]. Blue Economy has diverse components, including established traditional ocean industries, such as fisheries, tourism, and maritime transport as well as new and emerging activities, such as offshore renewable energy, aquaculture, seabed extractive activities, and marine biotechnology and bioprospecting. Increased and sustained utilization of the Blue Economic resources has the potential to boost the economy of the society [7].

The enormous potentials of Blue Economy can be maximized through ICT, a general-purpose technology providing an indispensable platform upon which further productivity-enhancing changes, such as service, product and process innovations, can be based [8]. Digital technologies may be sustainably exploited using ICT to advance Blue Economy. The prospective pioneers of this agenda are Higher Learning Institutions (HLIs). In essence, HLIs have the potential of realizing the concepts of Blue Economy by properly utilizing the abundance of young minds [9]. HLIs have the responsibility to

[1] One that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low carbon, resource efficient, and socially inclusive (UNEP, 2011).

produce skilled manpower and conduct cutting-edge research in all strategic areas of the Blue Economy. The government has been supporting the HLIs through establishment of ICT Centers of Excellence, empowering local researchers and innovators in ICT, and promotion of new products [3].

In view of these facts, several research questions could come to mind: *are the curricula in HLIs tailored to support the Blue Economy agenda? Is the number of ICT experts produced in HLIs sufficient to support the agenda? How can Tanzania harness the massive potentials of ICT to advance Blue Economy, hence promoting sustainable socio-economic development?* Researchers agree that ICT should be used to address societies' pressing needs, such as hunger, poverty and poor health conditions through research and innovation. This paper discusses the possible roles that ICT could play in sustaining the Tanzania Blue Economy agenda. Specifically, we focus on HLIs and their role towards applying sophisticated emerging technologies in realizing and sustaining the Tanzania Blue Economy. Recognizing the potential role of HLIs in advancing technology, we investigate current technological developments and trends of applying ICT solutions in conservation and sustainability of marine resources for inclusive socio-economic development. Besides, the paper recommends potential reforms in HLIs, as key stakeholders and frontiers of technology, and structures for managing data from segments of Blue Economy. These recommendations may necessitate informed decision making and policy reforms.

2 Role of ICT in Blue Economy

The ICT can play a major role in sustaining the Blue Economy, if positively exploited to solve related challenges. With the advancement and proliferation of digital technologies, researchers and practitioners may exploit the capabilities of ICT to accelerate the success of Blue Economy in Tanzania. ICT can automate the business processes of all sectors of Blue Economy to enhance efficiency and optimize productivity while simultaneously promoting ocean health and country's economic growth. This article elaborates possible applications of ICT in fishing, aquaculture, fish marketing, and tourism.

2.1 ICT in Fishing

The use of ICT can reinvigorate the fishing industry and ensure its sustainability and improved welfare of Tanzania fishers, hence advancing the overall country's economy. Considering Tanzania as an example, small-scale fishers rely on their fishing experiences to plan for the next fishing sites. This approach does not guarantee the availability of adequate fishes and may create frustrations among fishers to lose their limited resources. To address the challenge, ICT based fish finder gadgets can be applied to instantaneously and accurately locate fish-rich sites [10]. Consequently, we can reduce unnecessary costs incurred during the manual fish finding approach where fishers can move to a number of locations searching for the best places.

Using the state-of-the-art technologies, such as Machine Learning (ML), highly accurate algorithms can be devised to locate the fish sites and their corresponding species by using previous fishing information [11]. This low-cost approach can be achieved

through a careful observation of the fishers to track their fishing records that may serve as a training dataset for the ML models. Figure 1(a) shows a sample of a mobile application which gives fish types and their locations. This application was developed by researchers of University of Dar es Salaam, Signal Processing Research Group.

Furthermore, ICT can facilitate emergency reporting and localization of fishers [12]. There have been a number of reported cases of missing and deaths of small-scale fishers due to emergency reasons, including boat sinks. If such events could be communicated without delay, then lives of fishers could be saved, thereby improving the reliability in the small-scale fishing industry. With the current state of ICT, a mobile application can be developed to track all registered boats and report vital information of the boats and fishers to the control center for timely assistance. Emergency cases, including overfishing and boat sink or fire tragedies due to technical challenges, can be seamlessly exchanged between communicating parties to allow provision of appropriate assistance.

Figure 1(b) shows a sample mobile based system that tracks registered boats (vessels) and allows exchanges of critical message exchanges. This system can reduce the risks due to losses of fishers and their fishing resources.

2.2 ICT in Aquaculture

ICT can provide cost-effective tools to automate the entire business process of aquaculture and improve its efficiency and productivity. ICT can, without human intervention, facilitate measuring, monitoring and controlling of water quality parameters (e.g., temperature, salinity, and pH) to ensure optimal fish growth and reduction of fish mortality rate. It has been widely reported in the literature that the quality of water and feeding behavior can adversely affect the fish growth rate. This observation adds extra operational cost as the fish will need more time before attaining the market weight [13].

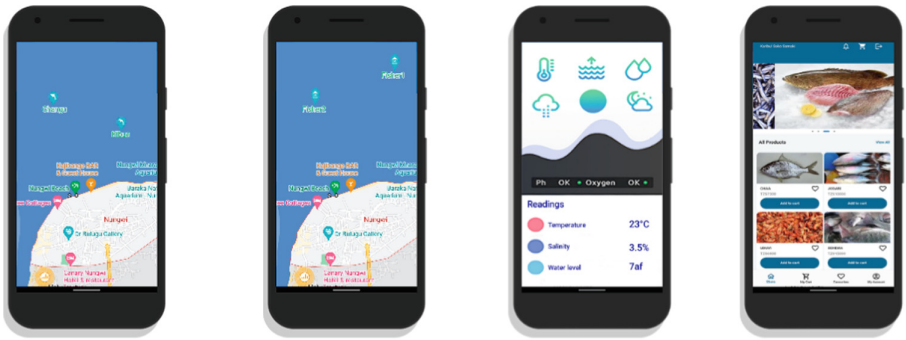
Using ICT solutions, the user can, in real-time, monitor the pond status, such as water level, and respond appropriately to maintain the optimum operating conditions. Also, the system can establish semi-automated or automated feeding schedules taking into account the age of the fish. Besides, the system can timely report all critical issues that may jeopardize the fish growth. Such a sophisticated system can significantly reduce the manpower without compromising productivity, an advantage that may maximize profit. The system may, in addition, create employment in the aquaculture industry and benefit both fishers and the country. Figure 1(c) depicts a mobile application that monitors the health of a pond.

2.3 Digital Fish Market

Traditionally, fish introduced into the markets, geographical physical sites, necessitate travel of customer to the selling points without the knowledge of the market status. Physical markets are challenged by a number of factors, including inaccessibility during unfavorable conditions and insufficient information on the product availability, leading to wastage of time and resources. Such markets provide no direct link between sellers and potential customers. To alleviate these challenges, mobile fish markets have been widely applied whereby sellers use vehicles to reach potential customers. These movable

shops, unaffordable to many local fishers, unnecessarily add extra cost attributable to human resources as well as fuel and maintenance costs of the vehicles.

ICT may provide advanced tools for the development of an online interactive market that considers the existing business processes, such as auctions, to complement the physical market. Figure 1(d) shows a sample of an online fish market system. In the online interactive market, the buyer will not be obliged to travel but yet can view all the available market products and swiftly buy the selected products. Also, with the online system, the seller can generate timely reports for their business analysis. Through this system, buyers can confirm transactions online and a reliable courier will be notified for delivery services, hence improving flexibility, adding convenience, and significantly reducing cost to the buyer. The system can create employment opportunities across various players in the Blue Economy ecosystem.



(a) (b) (c) (d)

Fig. 1. Sample mobile applications (a) fish types and locations (b) vessel tracking (c) aquaculture monitoring (d) digital fish market.

2.4 ICT in Tourism

Development of the tourism industry depends on the effective and high-speed ICT infrastructure and software applications. The tourism management system requires tourists' data to be accessed at different levels. The tourism attraction sites and other products should be readily available through the use of technology-based dissemination mechanisms, including dedicated broadcasting channels and social networks, to ensure that the intended information reaches a wider community. Customers should have the ability to share information and ratings on destination, quality of services for hotels and restaurants, and environmental and social conditions.

The current challenges in the tourism industry include undertrained tour guides which then lowers the tourists' security and safety, a consequence that may reduce the number of potential tourists. To overcome such a challenge, mobile applications can be developed to automate the processes by providing auto-guides and translations (multilingual customized geo-maps).

3 State of the Blue Economy in Tanzania

There have been commendable efforts by the Tanzanian government to establish the Blue Economy in country [14, 15]. The National Five-Year Development Plan 2021/2022–2025/2026 (FYDP III) has established several strategies to ensure positive transformation of the fisheries industries, including utilization of the Blue Economy potentials for marine and fresh waters. The FYDP III has recommended effective methods to achieve a sustainable Blue Economy, hence promoting freshwater and deep-sea fishing, marine and freshwater conservation, and aquaculture. For instance, the government has been argued to facilitate fishing activities through procurement of fishing vessels and construction of fishing harbors.

In different occasions, the current presidents of Tanzania, H. E. Samia Suluhu Hassan, and Zanzibar, H. E. Hussein Mwinyi, have strongly supported the Blue Economy as a feasible approach to address most socio-economic problems. In Zanzibar, the initiative to establish the Blue Economy Policy[2] started since October 2020 to ensure sustainable utilization of marine resources. Similar efforts are expected to be duplicated in the Tanzania mainland. Generally, these efforts provide a promising future for Tanzania to accomplish the goal of the FYDP III: "realizing competitiveness and industrialization through human development."

Tanzania and France are members of the Indian Ocean Rim Association (IORA)[3]—a dynamic inter-governmental organization with two primary objectives: strengthening of regional cooperation; and sustainable development within the Indian Ocean. As IORA members, the two countries will interact more closely in activities related to Blue Economy: tourism; safety and security; trade and investment; academic, scientific and technological exchanges; fisheries management; disaster risk management; and women's economic empowerment. These encouraging efforts by the government provide a promising future for Tanzania to achieve sustainable socio-economic development through Blue Economy.

Some HLIs in Tanzania have been engaged in various ways to foster Blue Economy. The Open University of Tanzania (OUT), for instance, has designed curricula in response to the Blue Economy[4]. Emphasizing the initiative, H. E. Hussein Mwinyi commended the achievements and challenged OUT to produce more curricula of Blue Economy to address the growing national and societal needs and aspirations. Despite the existing efforts, our investigation reveals that more work is needed by HLIs to manifest the envisaged Blue Economy. OUT, in particular, has demonstrated a way towards this promising technology. For the case of Tanzania mainland, HLIs may need to adapt the efforts demonstrated by OUT.

In this work, we investigated 24 HLIs to learn how their curricula contain components necessary for students to conceptualize and advance the Blue Economy (Fig. 2). Specifically, our goal centered on the contribution of ICT offered by HLIs towards the sustainable Blue Economy. The rationale for this goal is that ICT plays a primary role in providing suitable technological tools to promote and enhance the development of Blue

[2] http://www.planningznz.go.tz/.

[3] https://www.iora.int/en.

[4] https://www.out.ac.tz/out-design-curricula-in-response-to-the-blue-economy/.

Economy. Results from Fig. 2, however, show that we still have a long way for HLIs to sufficiently support Blue Economy through ICT programs. Approximately 29% of the twenty-four selected universities lack ICT programs, and the remaining universities contain an inadequate number of ICT programs. This observation further supports a need to reform the curricula for HLIs by incorporating more ICT programs, especially those directly linked with Blue Economy. We should aim to generating a considerable number of well-trained ICT students that can foster our vision of achieving a sustainable Blue Economy.

Migration towards Blue Economy requires collaborative efforts by academia, government, and industries. These entities should work together in varied capacities to realize the envisaged technology. Supported by the Tanzanian government, industries, stakeholders, and universities must undertake advanced research on Blue Economy. Researchers should be encouraged and supported to undertake multidisciplinary research focused on maximizing the potential benefits of marine and fresh waters while preserving the environment.

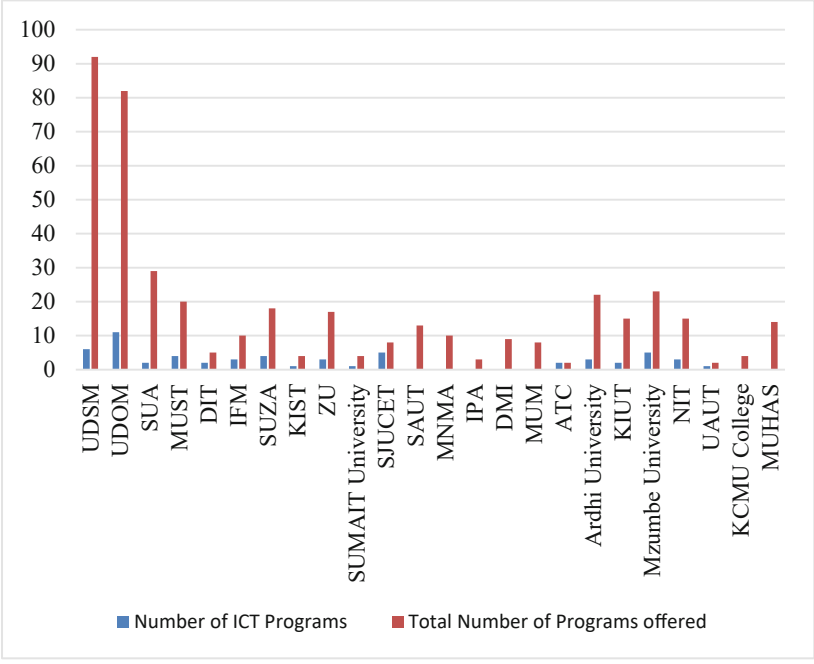


Fig. 2. ICT Programs offered by selected higher learning institutions in Tanzania.

4 Recommendations

The introduction of ICT in the Blue Economy sector cannot produce the intended benefits if unaccompanied by complementary organizational changes. A significant reform on the existing management structures should be made to create a conducive platform

to practically realize the concept of Blue Economy. The government should establish a one-stop data center in which data infrastructures, including data servers and associated systems, will be maintained. Furthermore, adequate ICT human resource (experienced developers and technicians) should be prepared to undertake technical tasks in the center. In this regard, the education system and curricula should, therefore, be adjusted accordingly to support the proposed concept.

4.1 Curricula Adjustment

Sustainability of Blue Economy needs preparation of skilled personnel to support ICT related matters required to foster the technology. ICT experts and professionals majoring in Blue Economy should be trained well, preferably through local universities and research centers. The Commonwealth of Learning[5] has shown the importance of establishing courses on Blue Economy to promote socio-economic development. Universities and the national research centers should establish new academic and professional programs at all levels to foster the implementation of the concept:

Curricula Review. Local universities should review their curricula, especially on the existing Blue Economy related programs, such as fisheries and aquaculture, marine sciences, fish markets, and tourism, to ensure the candidates acquire relevant ICT skills so that the graduates can digitize their respective business processes. Emerging technologies, including artificial intelligence, big data analytics, and internet of things should be considered as potential fields that experts should be equipped.

Professional Training. ICT, like other technologies, evolves with time. Hence, professionals should update their skills regularly to cope with the changes. Well-trained professionals can equip trainers with state-of-the-art technologies and practical knowledge. There should be well-defined training schedules and calendars with appropriate budgets to support the mission, achieved through the engagement of the HLIs and stakeholders in Blue Economy.

4.2 Blue Research in ICT

Higher learning institutions and other research organs in Tanzania should invest heavily in relevant research to maximize utilization of ICT in the Blue Economy sectors. The research centers should undertake applied research and disseminate their findings to respective stakeholders. Possible research areas include community networking, big data handling and visualization, automation and control systems, machine learning based fish monitoring, among others. Associated data will then be managed in a dedicated data center. Lessons may be taken from universities and research institutes that undertake research in Blue Economy: University of Seychelles[6], Middlebury Institute of International Studies[7], and Australia's Blue Economy Cooperative Research Center[8].

[5] https://vussc.col.org/index.php/2020/06/01/blue-econony/.
[6] https://beri.unisey.ac.sc/.
[7] https://www.middlebury.edu/institute/academics/centers-initiatives/center-blue-economy.
[8] https://eprints.utas.edu.au/37099/.

4.3 The Blue Data Center

Efficient information sharing systems among resource users and fishery managers are essential for the sustainable management of aquatic resources (Fig. 3). In that regard, data infrastructure, the so-called *Blue Data Center*, needs to be established through the ministry dealing with the Blue Economy. The data center should encompass all data related to the Blue Economy for research and decision making. The data should be accessible remotely by different users and the data level will be dictated by their respective roles in the business processes. This recommendation aligns with the FYDP III, which highlights the necessity of the National Data Center.

Expected data shall include, but not limited to, the following aspects:

Fisheries Information. A fisheries information system is expected to store fishing information, including types and locations of catches, types and capacity of boats, and fish weights. This information can be utilized to generate fish mapping for investigating fish behaviors with respect to time and other physical parameters.

Digital Fish Markets Information. The data center will also host the digital market platform. With the current trend where the physical market dominates, farmers and customers are operating probabilistically. The market status, which is highly affected by external factors, can hardly be determined. With the introduction of ICT based markets, domestic and industrial customers can view market status and place their orders without the need to physically visit the selling points.

Aquaculture Information. All registered ponds and their respective locations, unhealthy fishes, measurements of water quality parameters (salinity, pH, and ammonia), water levels and temperatures. Also, the amount of food reserve and any other related information and security alerts.

Tourism Information. All tourists' information, including airports of their flight origins, number of days spent in each tourism site, and their personal opinions on different matters associated with tourism.

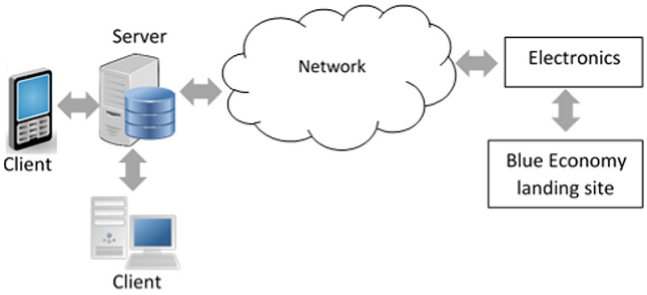


Fig. 3. Blue Economy data communication infrastructure.

5 Conclusion

In this paper, we have reviewed various concepts of ICT as a tool to support Blue Economy. Evidently, the advancement in ICT can facilitate the digitization of the Blue Economy ecosystem to efficiently and effectively sustain the agenda, hence attaining the intended benefits. Using the course catalogues and organizational structures of relevant departments in the selected institutions, we have reviewed the course curricula and research activities. Results show that, to fully exploit the power of the Blue Economy, serious reforms of course curricula and organization structures are urgently needed. This recommendation will ensure sufficient ICT skills to digitalize business processes of Blue Economy. In addition, effectiveness on the related operations of Blue Economy will be enhanced. We have also proposed some potential research avenues that may be considered to achieve sustainable Blue Economy in Tanzania. HLIs may explore the recommended research avenues and act appropriately towards realization of the envisaged ICT-driven Blue Economy. Immediate response by HLIs may accelerate the government agenda of building an inclusive and a sustainable Blue Economy.

Glossary for Fig. 2	
UDSM – University of Dar es Salaam SUA – Sokoine University of Agriculture DIT – Dar es Salaam Institute of Technology SUZA – The State University of Zanzibar ZU – Zanzibar University SAUT – St. Augustine University of Tanzania IPA – Institute of Public Administration DMI – Dar es Salaam Maritime Institute MUM – Muslim University of Morogoro ATC – Arusha Technical College NIT – National Institute of Transport KCMU – Kilimanjaro Christian Medical University	UDOM – University of Dodoma MUST – Mbeya University of Science and Technology IFM – Institute of Finance Management KIST – Karume Institute of Science and Technology SJUCET – St. Joseph University of Tanzania MNMA – Mwalimu Nyerere Memorial Academy University KIUT – Kampala International University in Tanzania UAUT – United African University of Tanzania MUHAS – Muhimbili University of Health and Allied Sciences

References

1. Sedoyeka, E., Sicilima, J.: Tanzania national fibre broadband backbone: challenges and opportunities. Int. J. Comput. ICT Res. **10**(1), 61–92 (2016)
2. Mango, C.: Local people participation through equity in private mobile telecommunication companies - towards effecting the Tanzania national development vision of 2025: an assessment of legal barriers. SSRN Electron (2015)
3. URT: National Five Year Development Plan 2021/22–2025/26-Realising Competitiveness and Industrialisation for Human Development. United Republic of Tanzania (2021)
4. Zonienė, A., Valiulė, V.: Tvaraus investavimo galimybės plėtojant mėlynąją ekonomiką. Reg. Form. Dev. Stud. **33**(1), 164–171 (2021)

5. Tonković, A.: Gunter Pauli: Plava ekonomija. 10 godina, 100 inovacija, 100 milijuna radnih mjesta Izvješće podneseno Rimskom klubu. Sociologija i Prostor **51**(1), 150–154 (2013)
6. Spamer, J.: Riding the African blue economy wave: a South African perspective. In: 2015 4th IEEE International Conference on Advanced Logistics and Transport, France, pp. 59–64. IEEE (2015)
7. Slay, H., Dalvit, L.: Red or blue? The importance of digital literacy in African rural communities. In: 2008 International Conference on Computer Science and Software Engineering, Wuhan, China, pp. 675–678. IEEE (2008)
8. Spiezia, V.: Are ICT users more innovative? An analysis of ICT-enabled innovation in OECD firms. OECD J. **2011**(1), 1–21 (2011)
9. Cross, M., Adam, F.: ICT policies and strategies in higher education in South Africa - national and institutional pathways. High. Educ. Policy. **20**(1), 73–95 (2007). https://doi.org/10.1057/palgrave.hep.8300144
10. Haag, M., Lambert, J., Waddell, J., Crampton, W.: A new and improved electric fish finder with resources for printed circuit board fabrication. Neotrop. Ichthyol. **17**(4), 1–10 (2019)
11. Li, Y., Chen, N., Chen, L.: Fishing techniques classification based on Beidou trajectories and machine learning. In: ACM International Conference Proceeding Series. Marseille, France, pp. 123–126 (2020)
12. Janet, M.: The impact of radio and mobile-wireless (ICT) in fishing industry: a case-study of Muttom region in Kannyakumari district. Int. J. Inf. Sci. Comput. **5**(2), 1–6 (2011)
13. Hamed, S., Jiddawi, N., Poj, B.: Effect of salinity levels on growth, feed utilization, body composition and digestive enzymes activities of juvenile silver pompano Trachinotus blochii. Int. J. Fish. Aquat. Stud. **4**(6), 279–283 (2016)
14. Semboja, J.: Realizing the blue economy in zanzibar: potentials, opportunities and challenges. Uongozi Inst. (2021)
15. Hafidh, H., Mkuya, S.: Zanzibar and the establishment of blue economy strategies. J. Resour. Dev. Manag. **74**(1), 34–39 (2021)