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Prospects for Aquaculture Development in Africa:

A review of past performance to assess future potential

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Prospects for Aquaculture Development in Africa

A review of past performance to assess future potential

Etienne Hinrichsen, John K. Walakira, Sandra Langi, Nabil Ahmad Ibrahim, Victoria Tarus, Olanrewaju Badmus and Heike Baumüller

Abstract

African aquaculture production has gradually increased over the years, but progress is still slow. Given large variations between African countries with regard to the availability of water, the macro-economic context, access to capture fisheries resources and other factors, the performance of African countries in aquaculture cannot be considered only by absolute production levels or contribution to GDP. Additional indicators must be considered that also take into account the role of aquaculture as a source of food supply as well as other macro-economic variables, such as population size and natural resource endowment.

To this end, relevant data were collected for 54 African countries covering a range of indicators, drawing on existing data collections of the World Bank and the Food and Agriculture Organization of the United Nations (FAO). The need for development of the sector and its potentials are identified by assessing African countries' performance with regard to the role of aquaculture as a source of food supply, absolute and per capita production volumes and values (including changes over time), and the economic importance of the sector.

The contribution of aquaculture to national fish supply is highest in Egypt. Lesotho features second in this indicator, but much of the production is targeted at the export market as confirmed by the low level of per capita fish supply. The greatest gap between per capita fish supply and average African fish supply was recorded for Ethiopia (followed by Guinea-Bissau and Sudan).

Egypt also leads African aquaculture in terms of absolute production volumes and value (followed by Nigeria). In 2018, Egypt's production was more than twice the total production of all the remaining African countries put together. In terms of production growth rates over the past decade, however, other countries stand out, including Rwanda, Burundi, Lesotho and Benin, albeit starting from a low base. Lesotho, South Africa and Mauritius lead in the value of production per tonne due to the cultivation of a number of high-value species for export.

In terms of the economic importance of the aquaculture sector, its contribution to GDP is highest in Egypt, followed somewhat surprisingly by Lesotho, a country in which there was no aquaculture a mere two decades ago and where today the sector is a significant earner of foreign currency. Egypt also leads with regard to output relative to available renewable water resources (followed by Uganda).

The study outlines a number of policy and investment priorities to support the growth of a sustainable, climate-resilient and equitable aquaculture sector in Africa as an integral part of food systems. Particular attention should be paid to engaging and building the capacities of small-scale actors in this sector to contribute to local food security, employment and income generation.

Keywords: Aquaculture, fisheries, fish feed, fish seed, production systems

JEL codes: E23, F1, Q22

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Table of contents

List of Tables, Figures and Maps

1 Introduction

This study aims to provide fresh insights into structure and performance of the aquaculture sectors in Africa. The situations of countries are assessed and preliminary policy implications and indications of potential development investments in the sectors are indicated.

Globally, aquaculture has been steadily increasing while wild aquatic catches have stagnated over the last two decades (FAO, 2020a). In Africa, aquaculture production has gradually increased over the past years, but progress is still slow even though the continent holds some of the greatest unexploited potential for aquaculture growth (Msangi and Batka, 2015). Reasons for the slow development of African aquaculture despite the apparent abundance of natural resources and a growing demand for food include a lack of infrastructure and development capital, inadequate information, limited technological know-how, and poor governance, among others. There is merit to be found in these reasons, but the causal factors differ greatly from region to region and from country to country.

Given the vastness of the continent and the variation between African countries, it is not surprising that aquaculture output differs greatly from country to country. Egypt, for instance, is the second largest global producer of tilapia after China. Aquaculture as an alternative source of protein for African nations holds huge potential to contribute to food security if resources are optimised sustainably through evidence-based technological and institutional innovations (Brummett & Reg, 1995; Brummett & Williams, 2000; Chan et al., 2019; Jamu & Ayinla, 2003).

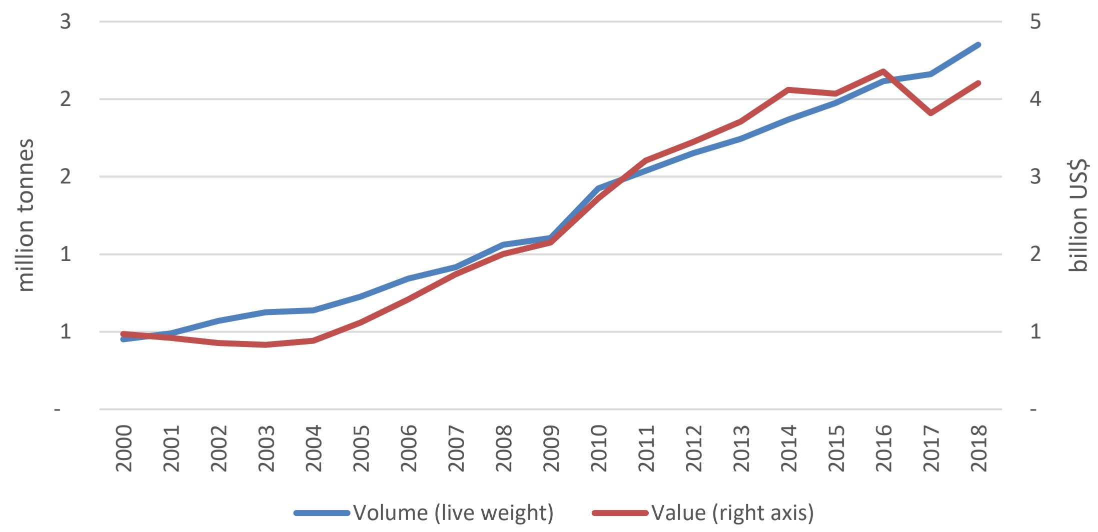
Much of the analysis of aquaculture development in Africa seeks to single out the top producing countries to learn from the approach that has been taken and to apply this approach to countries that are slow in progress. Likewise, the countries where aquaculture has not grown are often highlighted to show failures that should not be emulated. These comparisons are mostly based on the absolute production output, with little consideration given to a multitude of factors that determine and define the character of a country's aquaculture sector, and its efficiency or productivity. To assist in a more differentiated understanding of the sector, this study seeks to provide clarity and a greater focus on the characterisation of African aquaculture by country, based on a wider range of indicators beyond production levels.

2 Overview of the African aquaculture sector

General trends

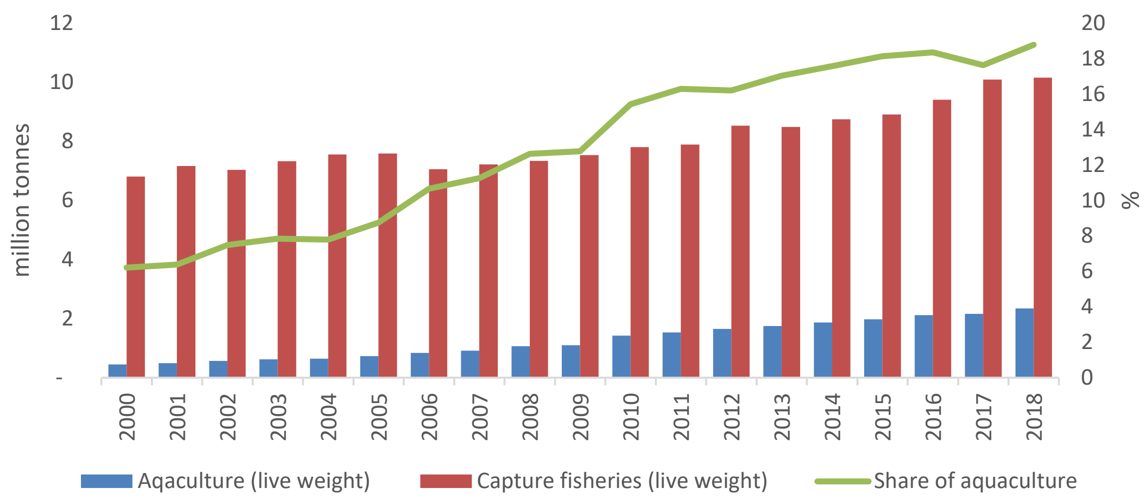
The volume of aquaculture production in Africa increased almost five-fold over the past two decades while its value rose almost ten-fold (Figure 1). At the sub-regional level, the highest production levels are found in North Africa, notably Egypt. Production levels in West and East Africa follow at a distant second and third position respectively. Aquaculture production on the continent is lowest in Southern and Central Africa. In absolute numbers, production levels in Africa are still low, accounting for just 2.7 percent of global production in 2018, highlighting a significant potential for expansion. The contribution of aquaculture to national GDP increased in most African countries between 2009 and 2018, but it is still negligible at less than 2 percent in 2018. Capture fisheries remains the dominant source of fish on the continent, with aquaculture accounting for 16-18 percent of total fish production in 2018 (FAO, 2020a) (Figure 2).

Figure 1: Volume and value of aquaculture production in Africa 2000-18



Data source: FAO (2021)

Figure 2: Contribution of aquaculture in total production of aquatic foods in Africa



Data source: FAO (2021)

Production Systems

Aquaculture production in Africa is a very diverse sector in terms of technologies used, natural resources, and value chain structures. Predominantly it takes place in inland waters (82 percent of production volumes) (FAO, 2021). Ocean-based aquaculture is mainly being practices in the Mediterranean and Black Sea (70 percent of marine production) as well as the Indian Ocean (29 percent). Production systems can be categorised as extensive, semi-intensive or intensive. The main production systems in sub-Saharan Africa are earthen ponds, cages and basins (Satia, 2017).

In **North Africa**, extensive systems are characterised by stocking of juvenile fish in reservoirs as practiced in Egypt, Morocco, Algeria and Libya (El-Sayed, 2017). Semi-intensive aquaculture is practiced exclusively in earthen ponds and is characterized by higher levels of production and supplementary feeding. Semi-intensive aquaculture systems are predominant in Egypt (El-Sayed, 2017) and account for up to 80 percent of total fish production (Soliman, 2017). Intensive systems in tanks and cages are also rapidly developing.

Production systems in **Southern Africa** include raceways (artificial channels) for trout production, ponds for extensive and semi-intensive production, cages for grow out, longlines for mussel and oyster production, shallow flow through systems in baskets for oyster production and recirculating aquaculture systems (RAS) (Satia, 2017; Adeleke et al., 2020; FAO, 2021). Compared to other African countries, RAS has been largely adopted in South Africa (Adeleke et al., 2020). Abalone farming is conducted in land-based pumping systems utilizing highly engineered hatchery technology and concrete or plastic tanks (Satia, 2017). Cage fish farms also contribute significantly to aquaculture production in the Southern African region. For instance, in Zambia two cage farm companies account for about 85% of the cages on Lake Kariba.

Aquaculture in **East Africa** is predominantly extensive pond-based because of the lower cost of infrastructure development and necessary know-how compared to intensive systems (Mwima et al., 2012). Some farmers and companies have adopted intensive production methods such as cages, which is profitable and has reduced capital investment per unit of fish produced (Satia, 2017). Among East African countries, Uganda has the highest number of inland cage farms at 18 percent, followed by Kenya, Tanzania, Rwanda, Zimbabwe, Zambia and Malawi (Musinguzi et al., 2019). In the United Republic of Tanzania and the Republic of Mozambique, seaweed farming is carried out using the 'tie-ti'" system in shallow intertidal lagoons (Satia, 2017). There are also components of integrated agri-aquaculture systems reported in the Republic of Malawi and Uganda (Satia, 2017). Among African inland water bodies, Lake Victoria has the highest number of caged aquaculture facilities (Musinguzi et al., 2019).

In **West Africa**, specifically in Guinea, Côte d'Ivoire and Cameroon, dam ponds (dams closing a valley to create a large pond) are also utilized (Satia, 2017). Furthermore, the use of integrated agri-aquaculture systems in Benin and Nigeria have also been reported (Satia, 2017). Cage fish farming is the preferred form of aquaculture for industrial privately owned farms who produce 1,000 to 10,000 tonnes or more/year.

Fish Feed

The increase in African aquaculture production is accompanied by a growing production of fish feed. Prior to 2010, feed mills mainly produced feed for terrestrial animals and only supplied fish feeds upon request from farmers (Agboola et al., 2019). This was due to low demand which made it difficult for feed manufacturers to provide their own production lines for aqua feed (Hassan et al., 2007; Agboola et al., 2019). The increase in aquaculture production on the African continent can partly be attributed to a shift from extensive to semi-intensive/intensive systems (Waite et al., 2014), as evident particularly in Egypt. This shift has greatly contributed to the increased feed demand as intensive systems are feed-dependent (El-Sayed et al., 2015). As a result, local capacity to produce or procure more feed was developed, such as the establishment of additional feed mills or increased feed imports. In Egypt, for instance, the number of feed mills increased from five mills producing 20,000 tonnes of feed annually in 1999 to 73 mills producing approximately 1 million tonnes per year in 2017 (Shaalan et al., 2018). Nigeria has the highest number of feed mills in Sub-Saharan Africa which produce 60 percent of the local aquafeeds used in the country (Adeleke et al., 2020). However, these feed mills have a low production capacity, with an output ranging from 0.5 to 3 tons of feed produced per hour.

Large scale aquaculture investors in several Sub-Saharan countries, such as Nigeria, Uganda, Kenya and Zambia, still rely heavily on imported aquaculture feeds and ingredients due to the higher quality, better value for money, inadequate local production and competitive use of ingredients in other areas of animal production (Adedeji & Okocha, 2011). Accordingly, feed manufacturers in these countries have established regional feed mills or outlets to meet the demand for improved aquaculture feeds.

Regardless of the intensity of production, both the fish feed industry and farmers are faced with rapidly increasing prices of feed ingredients and feed respectively (El-Sayed, 2014, Mustapha, 2020). The issue of feed is of economic concern given that feed accounts for more than 50 percent of total production costs (Hasimuna et al., 2019) and hence determines the viability and profitability of the aquaculture enterprise. As previously stated, there is additionally the challenge of inadequate supply of quality fish feed (Hasimuna et al., 2019) as well as lack of trained personnel in areas of aquaculture nutrition i.e., formulation and processing (Udo & Umana, 2017). For small-scale farmers, who sometimes produce their own feeds, nutritional value is also of concern (Mustapha, 2020). This offers investors the opportunity to produce local high-quality feed at lower prices, which reduces farmers' costs and thus promotes cost-efficient production. Previously, in the majority of Sub-Saharan African countries (except Nigeria), local demand for aquafeeds had not reached a critical mass for appropriate attention and investment (Hassan et al., 2007). This is currently changing with companies like Aller Aqua, Novatek, and Skretting setting up aquafeed mills on the continent to serve their clients in the region.

Fish Seed

The availability and quality of juvenile fish for stocking have been repeatedly cited as one of the main barriers to aquaculture development in Africa (Brummett, 2007; Shaalan et al., 2018; Hasimuna et al., 2019). Fish seed are mainly collected from the wild (wild catch), from production ponds or from licensed/unlicensed hatcheries (Brummett, 2007; Shaalan et al., 2018). Sourcing seed from the wild is highly discouraged due to biosecurity concerns, unreliability and lack of sustainability (Bondad-Reantaso, 2007). The number of hatcheries on the continent has increased significantly compared to two decades ago, mainly attributable to the private sector. However, the majority are small scale (Brummett, 2007) and produce primarily Nile tilapia (*Oreochromis niloticus*) and African catfish *(Clarias gariepinus*) fingerlings. The main hatchery systems include small open ponds, hapas (fixed net enclosures), indoor tanks and concrete tanks (Brummett, 2007). Other hatchery systems include indoor flow-through tanks and indoor recirculating raceways. In Egypt, for instance, there are between 400 and 500 private hatcheries producing sex-reversed tilapia. However, only 150 are licensed (Hebisha & Fathi, 2014).

The demand gap for quality brood stock and subsequently quality fingerlings is vast in Africa (Adewumi, 2015). This is due to several issues, including poor genetic management and deterioration of genetic quality of the parent populations (Brummett, 2007). Besides, there is a lack of standardised hatchery practices and insufficient quality control to regulate seed quality by government institutions. Additionally, biosecurity regulations and practices to minimize contamination are minimal or non-existent in several hatcheries (Brummett, 2007; Kajungiro et al., 2019). There is a need to explore advanced breeding technologies to develop new and improved fish seed strains.

3 Methodology

Given the large variation between African countries with regard to landmass, availability of water, macro-economic context, access to capture fisheries resources and other factors, the performance of African countries in aquaculture cannot be considered only by absolute production levels or contribution to GDP. Additional indicators must be considered that also take into account population size, changes over time, the role of aquaculture as a source of food supply, and the economic importance of the sector. To this end, relevant data were collected for 54 African countries covering the following indicators:

Fish supply and consumption	1. Total fish supply per capita 2. Contribution of aquaculture to national fish supply 3. Per capita shortfall to reach average African fish consumption
Aquaculture production	4. Absolute production volume (incl. growth rate) 5. Per capita production volume 6. Absolute production value (incl. growth rate) 7. Per capita production value 8. Value of production per tonne
Economic importance of the sector	9. Contribution of aquaculture to GDP 10. Aquaculture production by renewable water resources

This assessment relied heavily on data from statistical collections that are maintained by the World Bank and the FAO (see Annex 1 for further details on the data sources). The population and GDP data housed in the World Bank database are linked to that which is generated by the Organisation for Economic Co-operation and Development (OECD). These data are considered accurate but have certain limitations such as the use of a constant exchange rate from national currencies to US$ for the determination of GDP. Population data is based on national census data, which were collected at different times in different countries using different methodologies.

In the FAO's Fishery Statistical Collection (FAO, 2021), aquaculture is defined as the farming of aquatic organisms including fish, molluscs, crustaceans, and aquatic plants. For this assessment the harvesting of crocodiles was removed from the data contained in the FAO's Fishery Statistical Collections: Global Capture Production, as harvested crocodiles are given by number as opposed to mass.

The FAO's aquaculture and fisheries statistical collections have been questioned for their accuracy in the past. The data collection methods rely heavily on national inputs and the national methodologies in data collection are not aligned. In the Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000 (Aquaculture in the Third Millennium, 2001), the FAO highlights several challenges to data accuracy and suggests several means by which this should be addressed. For this assessment that made use of a metadata approach, the accuracy is considered adequate.

The results by indicator are shown for data from 2018 only, given that the average African fish consumption for 2018 is know from the FAO's The State of World Fisheries and Aquaculture 2020, and this number was used for calculation and comparative analysis in some of the results. For selected indicators, changes over time are also reported.

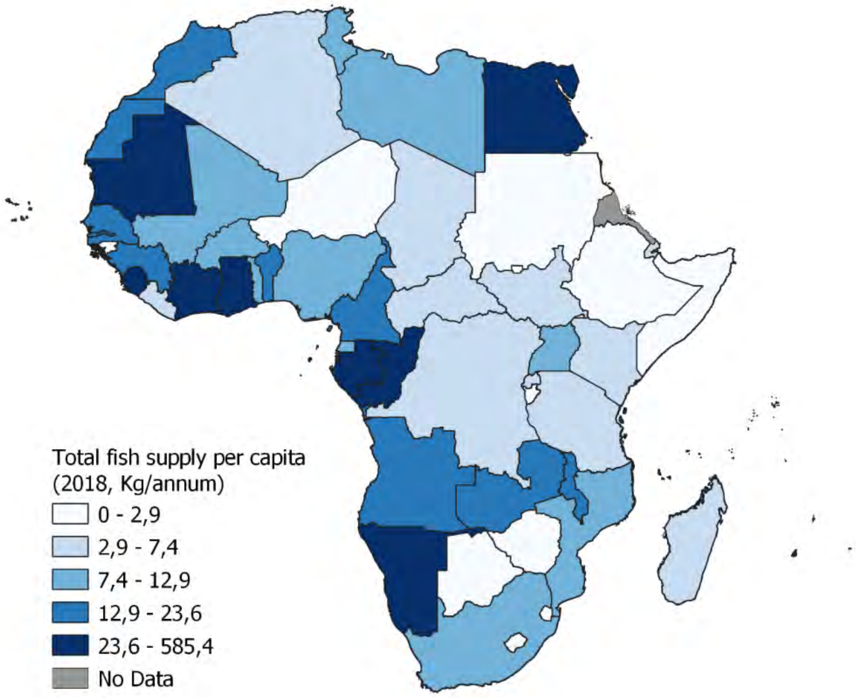
4 Assessing aquaculture-related indicators for Africa

Indicator 1: Total fish supply per capita

Total fish supply per capita per annum indicates how much fish is available per person in a country, supplied from aquaculture and capture fisheries, including imports and considering exports. Erroneous data for the Seychelles, likely due to misreporting of marine capture fishery exports, show an anomaly where fish supply per capita for the island state was calculated at 585 kg per capita. This is impossible as it would result in more than 1.5 kg of fish per person per day, and hence this result was excluded. In Namibia and Mauritius, the relatively low population density and strong marine fishery results in a very high fish supply per capita. All African countries in the top ten list of fish supply per capita are island or coastal nations where fish supply is bolstered by marine capture fisheries.

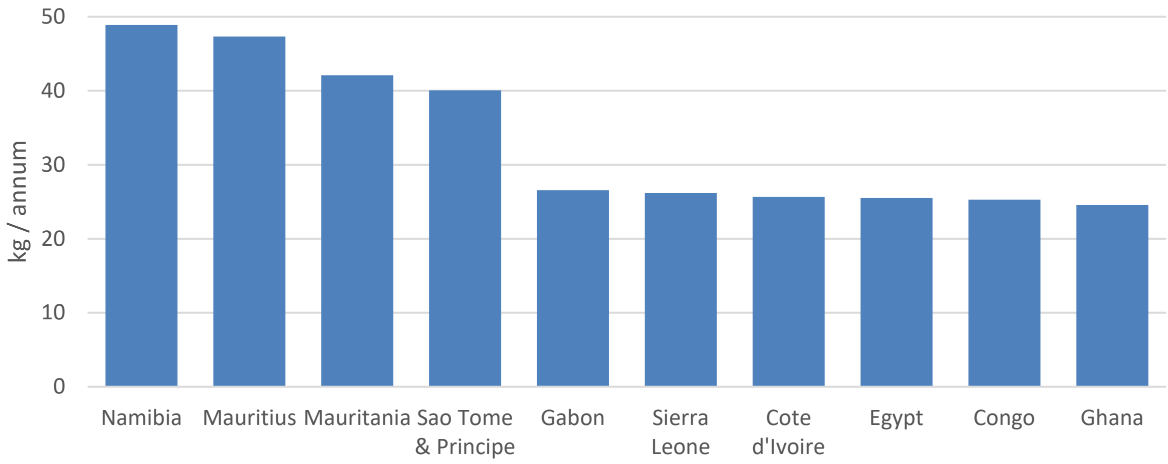
In 2018, average fish consumption per capita in Africa was 10 kg per person, compared to 20.5 kg globally (FAO, 2020a). Thirteen African countries have a higher total fish supply per capita than the global average – all of these being island or coastal nations (Map 1, Figure 4). Another 15 African countries (28 overall) have a higher total fish supply per capita than the African average of 10 kg. Of these countries, all but three (Zambia, Malawi, and Uganda) are island or coastal nations, clearly indicating that total fish supply per capita is generally higher for island and coastal nations.

Map 1: Per capita fish supply by country (2018)



Cartography: Paula Rothenberger. Data sources: FAO (2021) (production, trade); World Bank (2021) (population)

Figure 3: Top 10 countries by total fish supply per capita (2018)

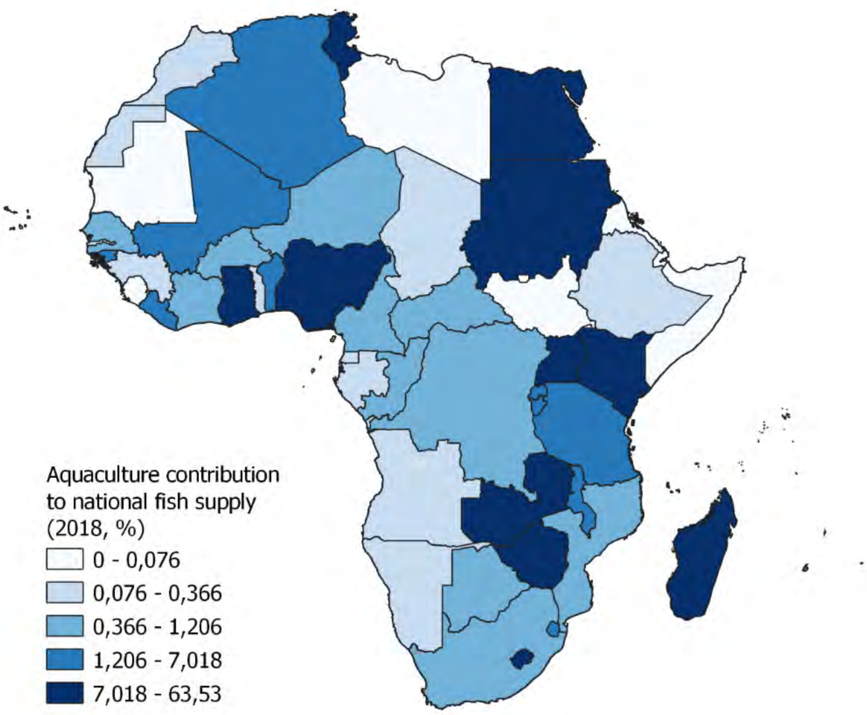


Data sources: FAO (2021) (production, trade); World Bank (2021) (population)

Indicator 2: Contribution of aquaculture to national fish supply

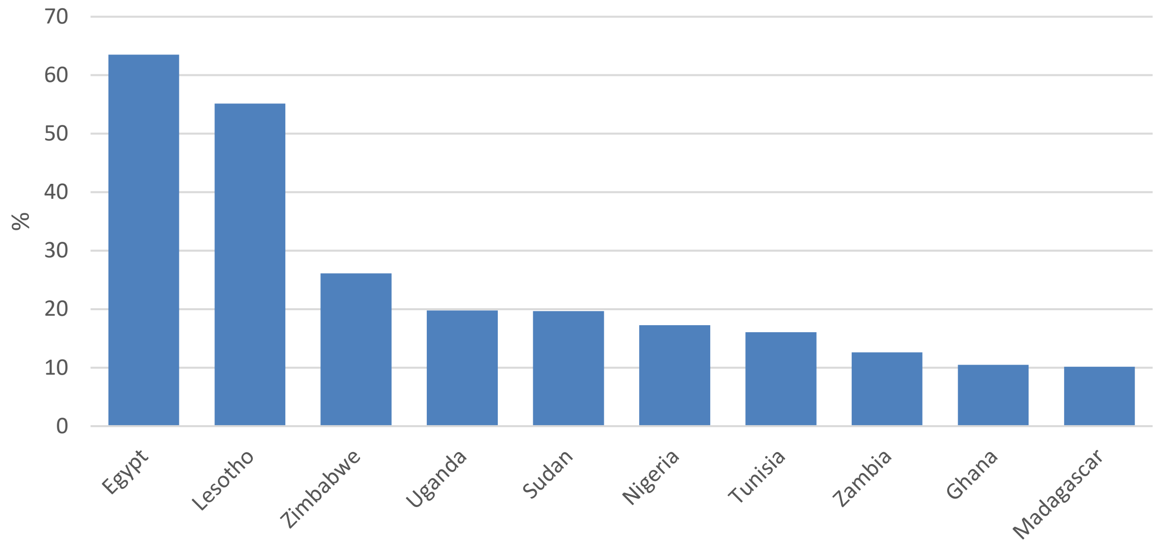
In determining the contribution of aquaculture to national fish supply, aquaculture production volume was calculated as a percentage of total national fish supply. The total national fish supply consists of total fisheries production volume plus import volumes, less export volumes. It should be noted that certain nations, specifically island nations, have access to significant capture fisheries resources and have relatively small aquaculture industries, and will therefore not feature strongly in this analysis. Egypt ranks highest, closely followed by Lesotho (Map 2,Figure 5). Lesotho's high value is a skewed indication caused by underreporting of the export volume, given that virtually the entire farmed crop of rainbow trout in Lesotho is exported.

Map 2: Contribution of aquaculture to national fish supply by country (2018)



Note: Total national fish supply = total fisheries production volume + import volumes - export volumes
Cartography: Paula Rothenberger. Data sources: FAO (2021) (production, trade)

Figure 4: Top 10 countries by contribution of aquaculture to national fish supply (2018)



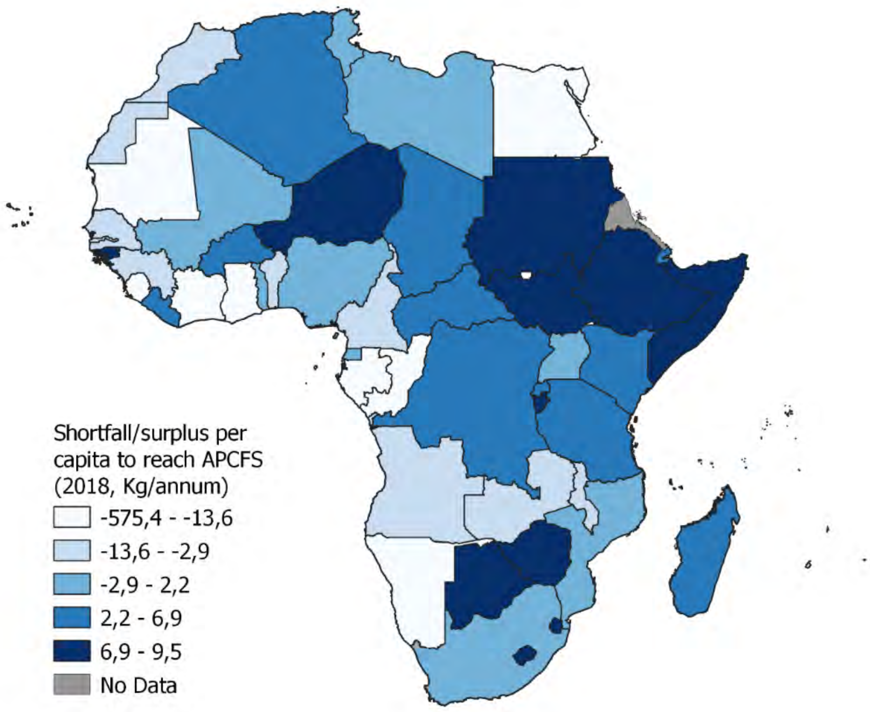
Note: Total national fish supply= total fisheries production volume + import volumes - export volumes
Data sources: FAO (2021) (production, trade)

Indicator 3: Per capita shortfall to reach the average African per capita fish consumption

Using the calculation for Indicator 1, it is possible to identify which African countries are furthest below the average per capita fish consumption in Africa (10 kg per person in 2018). Given that capture fisheries worldwide are at capacity or overfished, additional fish supply depends on aquaculture development. The list of ten African countries with the largest deficit relative to average per capita fish supply (APCFS) in Africa is therefore the list of countries where aquaculture development is potentially most important - although this crude assumption ignores the substitution potentials with meat, egg and milk products. Moreover, cultural food preferences also matter, as does the availability of development capital, expertise and the natural resources required for aquaculture.

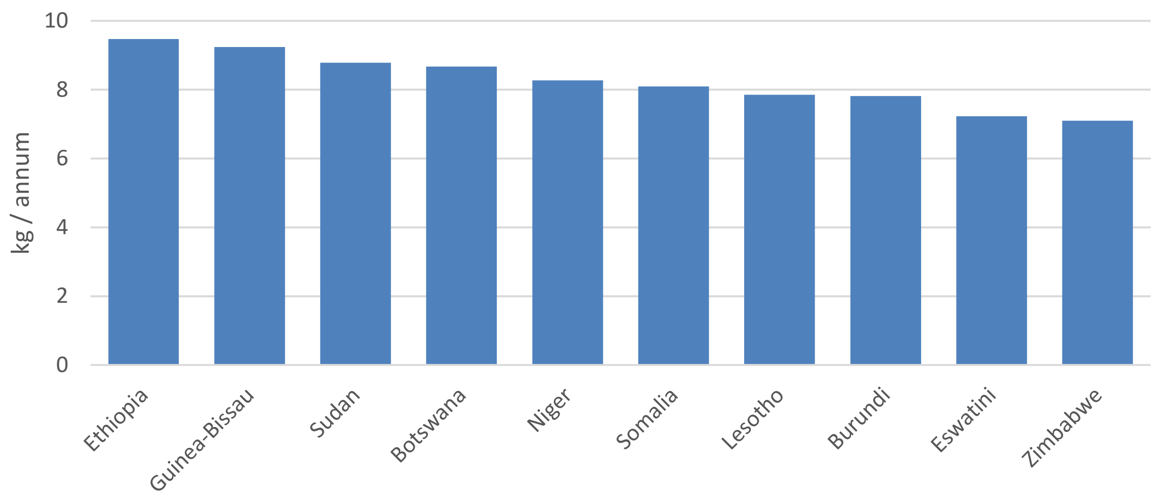
This list is topped by Ethiopia (shortfall of 9.47 kg per capita per annum) (Map 3, Figure 6). It is interesting to note that despite the high value of aquaculture production per capita in Lesotho, the per capita shortfall in total fish supply is high at 7.85 kg. This clearly indicates that aquaculture products are largely exported and do not contribute significantly to direct local food security.

Map 3: Per capita shortfall/surplus to reach average African per capita fish supply (2018)



Cartography: Paula Rothenberger. Data sources: FAO (2021) (production, trade); World Bank (2021) (population)

Figure 5: Top 10 countries with the highest per capita shortfall to reach average African fish supply (2018)

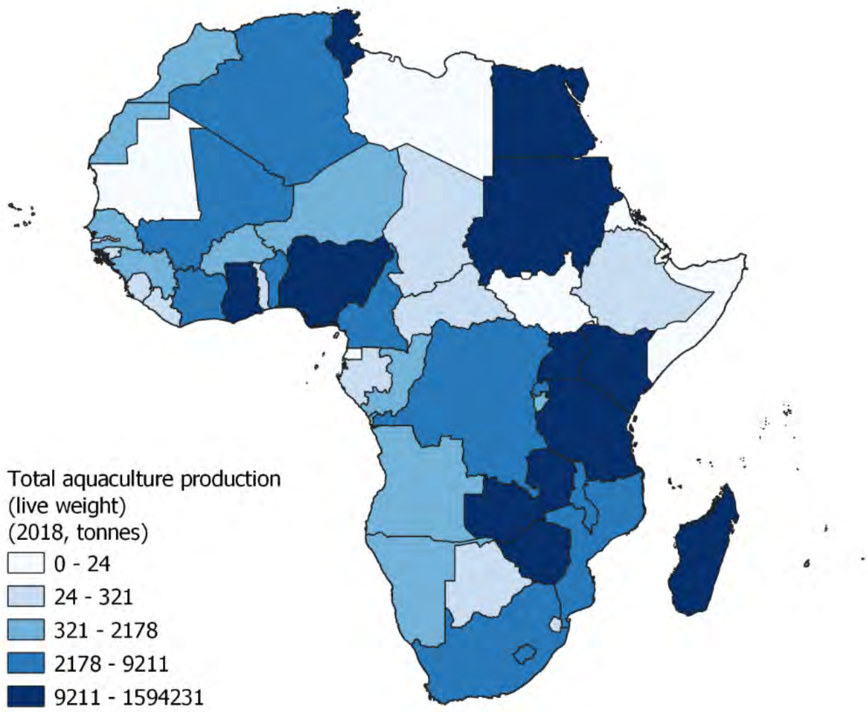


Data sources: FAO (2021) (production, trade); World Bank (2021) (population)

Indicator 4: Production volume

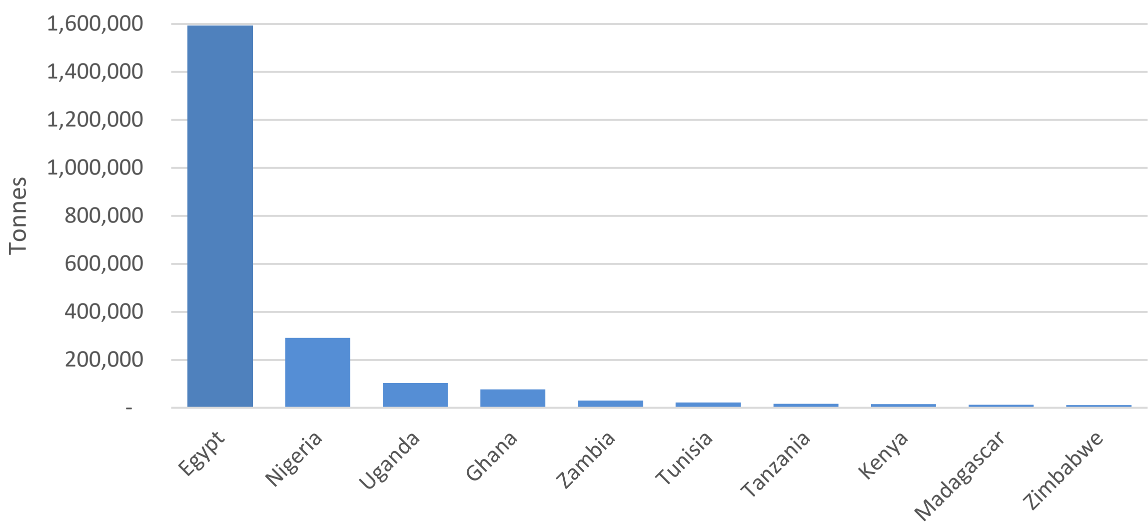
The total aquaculture production volume in Egypt alone (1.6 million tonnes for 2018) was more than twice the total production of all the remaining African countries (652,217 tonnes for 2018) (Map 4, Figure 7). Much of the Egyptian production is made up of tilapia. The second highest aquaculture output is that of Nigeria (291,323t for 2018), consisting mainly of catfish, followed by Uganda (103,737t for 2018), consisting mainly of tilapia. Of specific interest is the very low contribution of marine aquaculture output across Africa, despite an abundance of marine resources.

Map 4: Production volume by country (2018)



Cartography: Paula Rothenberger. Data source: FAO (2021)

Figure 6: Top 10 African countries by aquaculture production volume (2018)



Data source: FAO (2021)

Looking at production growth rates between 2009 and 2018 shows similar results among the top ten countries with the exception of Malawi which moved up from twelfth place (Table 1). A different picture emerges, however, when evaluating compound annual growth rates (CAGR) to assess growth in relative rather than absolute terms. Here, Rwanda, Burundi, Lesotho and Benin top the list with CAGR exceeding 30 percent. Egypt and Nigeria only exhibit growth rates of 8 and 7 percent respectively, given already high production volumes in 2009.

Table 1: Top 10 countries by growth in aquaculture production volumes

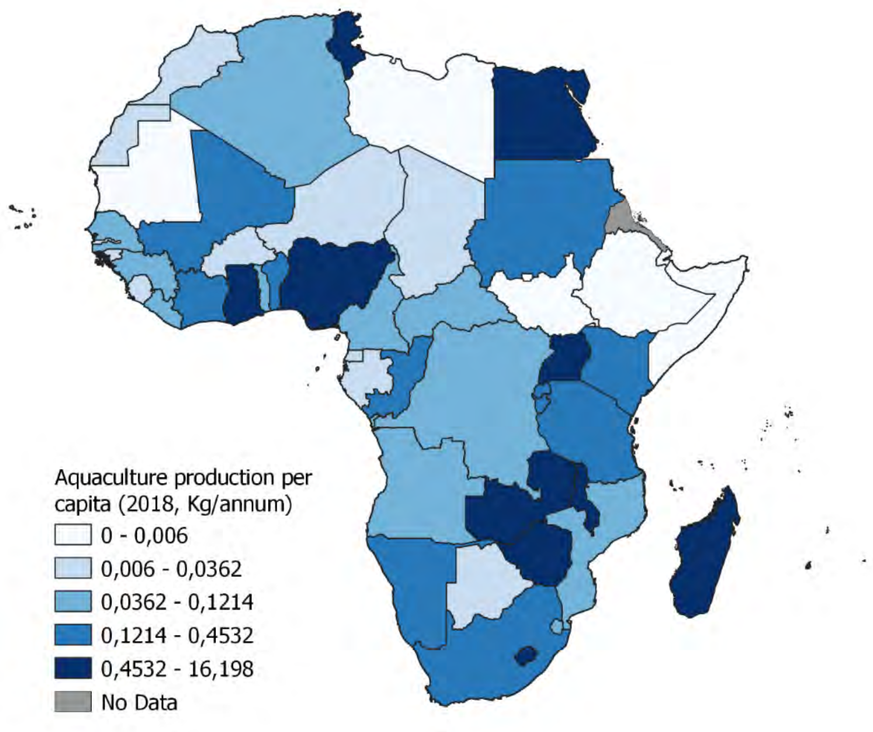
Rank	Country	Volume growth 2009-2018 (tonnes)	Country	CAGR (%)
1	Egypt	888,741	Rwanda	50
2	Nigeria	138,527	Burundi	41
3	Ghana	69,476	Lesotho	37
4	Uganda	27,083	Benin	32
5	Zambia	21,060	Senegal	32
6	Tunisia	16,919	Ghana	27
7	Tanzania	11,130	Angola	21
8	Kenya	10,825	Malawi	19
9	Sudan	10,000	Mauritius	17
10	Zimbabwe	8,255	Tunisia	16

NOTE: Calculated for countries with >1000 tonnes of aquaculture production (2018); CAGR = compound annual growth rate
Data source: FAO (2021)

Indicator 5: Production per capita

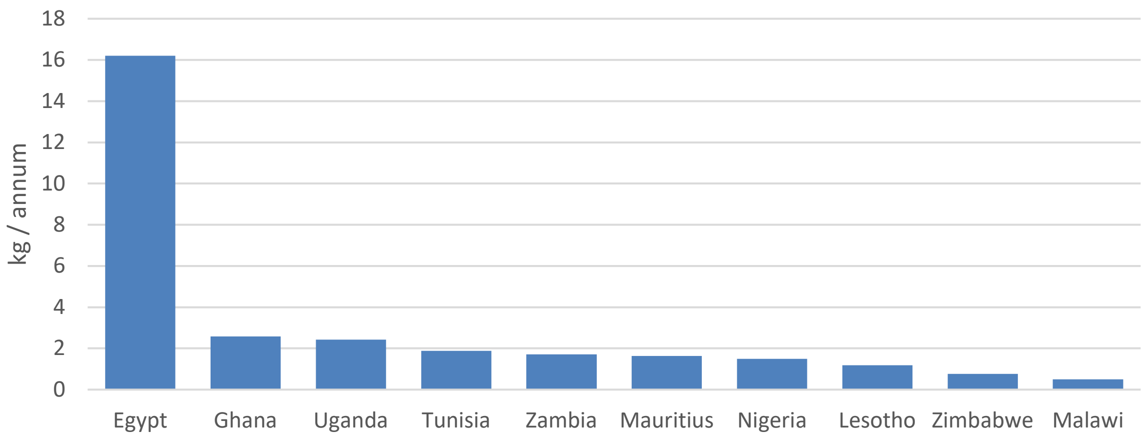
To better understand the national relevance of the aquaculture sector, it is insightful to relate the absolute volume of aquaculture production to the size of the population. The sheer volume of production in Egypt stands out from other countries, with around 16.2 kg of farmed fish produced per capita in 2018 (Map 5, Figure 8). This was followed by Ghana (2.6 kg) and Uganda (2.4 kg). The rapid increase in aquaculture production in Tunisia, Mauritius and Lesotho has resulted in these countries being among the top ten in terms of aquaculture production per capita.

Map 5: Per capita production volume by country (2018)



Cartography: Paula Rothenberger. Data sources: FAO (2021) (production); World Bank (2021) (population)

Figure 7: Top 10 countries by per capita aquaculture production volume (2018)

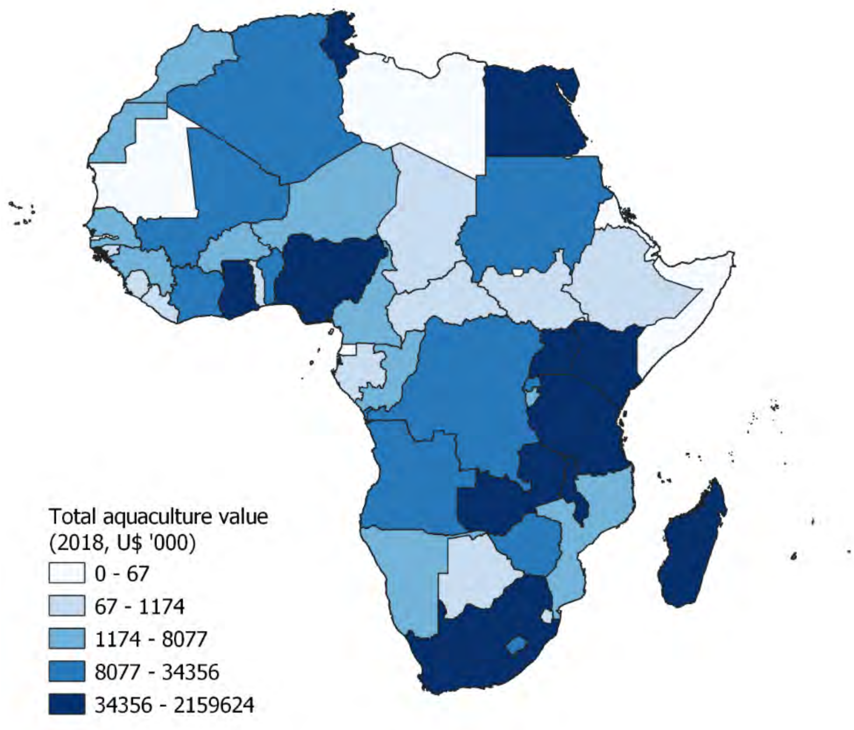


Data sources: FAO (2021) (production); World Bank (2021) (population)

Indicator 6: Production value

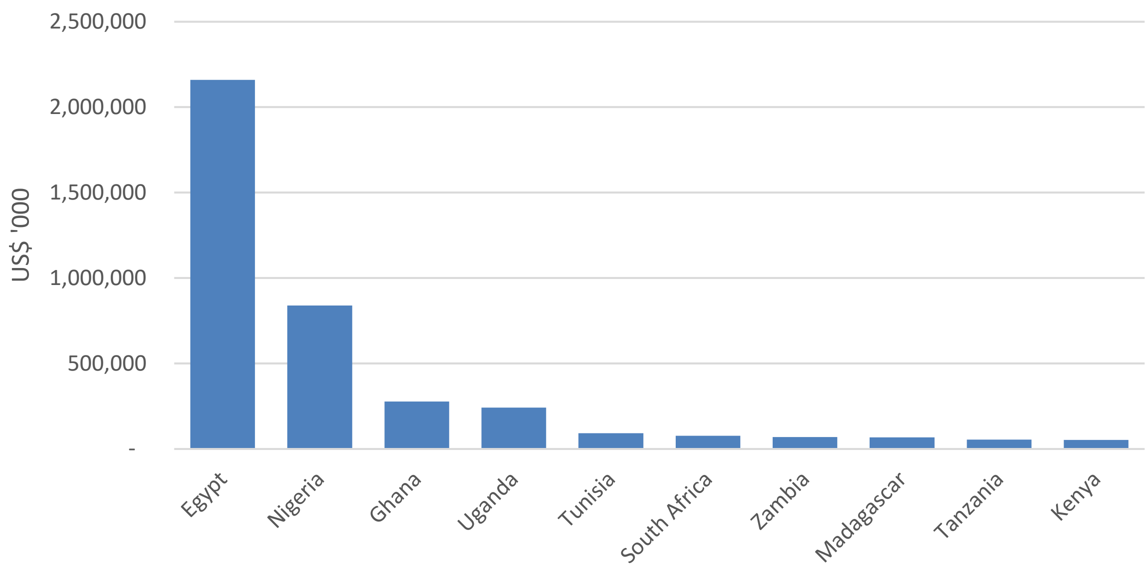
Given the significant production volume from Egyptian aquaculture, it is not surprising that the total value of Egyptian aquaculture is also the highest in Africa at US$ 2.16 billion in 2018 (Map 6, Figure 9). However, this value constitutes only about half (51%) of the aquaculture output value on the continent, pointing to the relatively low value of commodity aquaculture products in Egypt. The second highest aquaculture output value is that of Nigeria (US$ 8.4 million for 2018), followed by Ghana (US$ 2.77 million for 2018), even though its aquaculture output by volume is significantly less than that of Uganda which has the third highest output by volume. South Africa is an interesting case, ranking sixth for its aquaculture value, but only thirteenth in production volume. This is indicative of the high relative value of its marine aquaculture species (i.e., mussels, oysters, and abalone).

Map 6: Production value by country (2018)



Cartography: Paula Rothenberger. Data source: FAO (2021)

Figure 8: Top 10 countries by aquaculture production value (2018)



Data source: FAO (2021)

Looking at the growth in production values, the countries remain largely unchanged with regard to absolute growth in value, but similar to volume growth, Rwanda, Burundi, Lesotho und Benin rank highest when looking at annual growth rates (Table 2). Tanzania is an interesting case. While the country only reports a CAGR of 11 percent in terms of production volume, it reaches 45 percent in terms of value. The high growth rate in value may be due to a combination of several factors, such as increases in fish price resulting from declining natural stocks, rising seaweed prices and contributions from some Tanzanian islands in prawns.

Table 2: Top 10 countries by growth in aquaculture production value (2018)

Rank	**Country**	**Value growth 2009-2018 (US$ '000)**	**Country**	**CAGR (%)**
1	Egypt	803,476	Rwanda	60
2	Nigeria	408,993	Burundi	49
3	Ghana	252,846	Tanzania	45
4	Uganda	95,385	Lesotho	40
5	Tunisia	60,955	Benin	34
6	Tanzania	52,915	Senegal	30
7	Madagascar	46,788	Angola	29
8	Zambia	45,160	Ghana	27
9	Kenya	40,072	Niger	26
10	South Africa	38,851	Malawi	22

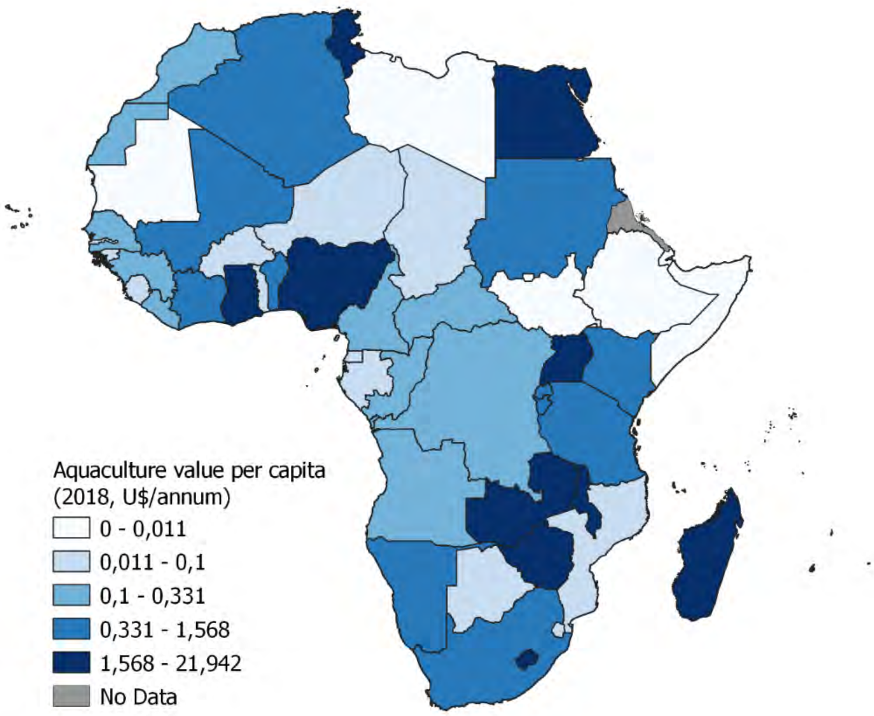
NOTE: Calculated for countries with >US$ 1million worth of aquaculture production (2018); CAGR = compound annual growth rate

Data source: FAO (2021)

Indicator 7: Value per capita

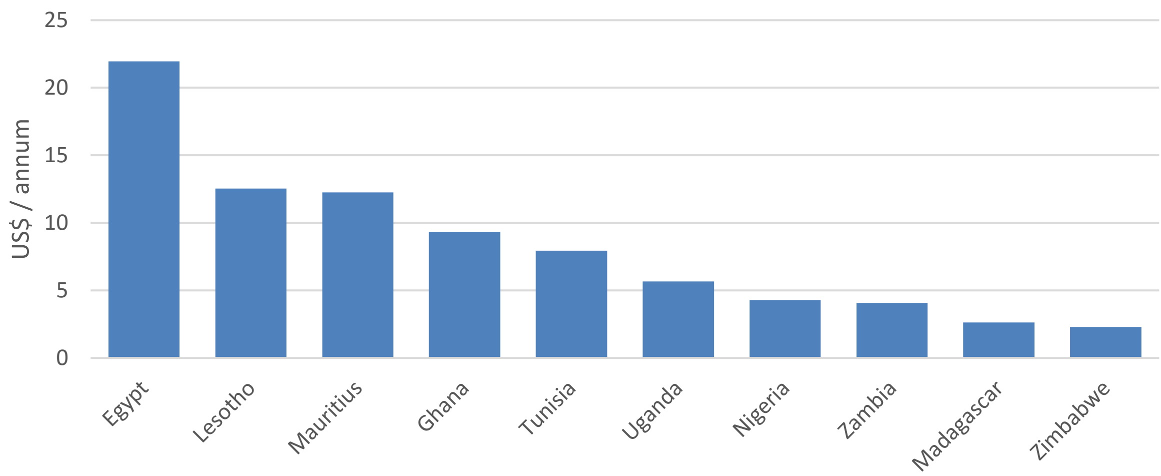
Calculating per capita rates of aquaculture production values again provides a helpful indicator of the economic importance of a country's aquaculture sector. The result of this calculation confirms that Egypt is the aquaculture powerhouse of Africa (Map 7, Figure 10). The aquaculture value per capita per annum reached US$ 21.94 in 2018, followed by Lesotho at US$ 12.55. This remarkable performance of Lesotho is based on the rapid development of a high-value rainbow trout sector in its cold mountain waters. The relatively high per capita value contribution in Mauritius is related to the rapid expansion of high-value marine aquaculture.

Map 7: Per capita production value by country (2018)



Cartography: Paula Rothenberger. Data sources: FAO, 2021 (production); World Bank (2021) (population)

Figure 9: Top 10 countries by per capita aquaculture production value (2018)

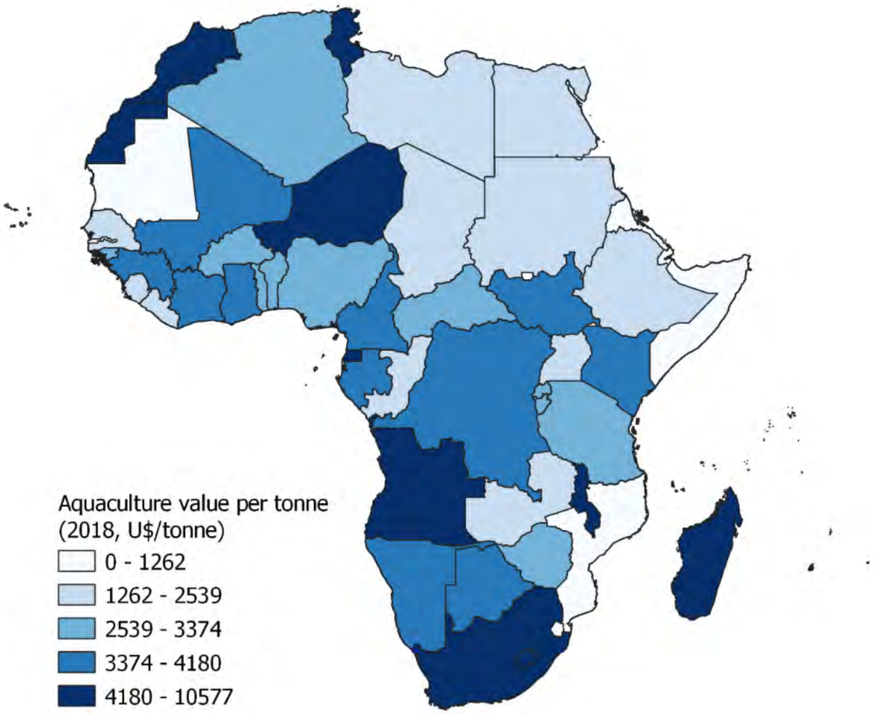


Data sources: FAO, 2021 (production); World Bank (2021) (population)

Indicator 8: Value per Tonne

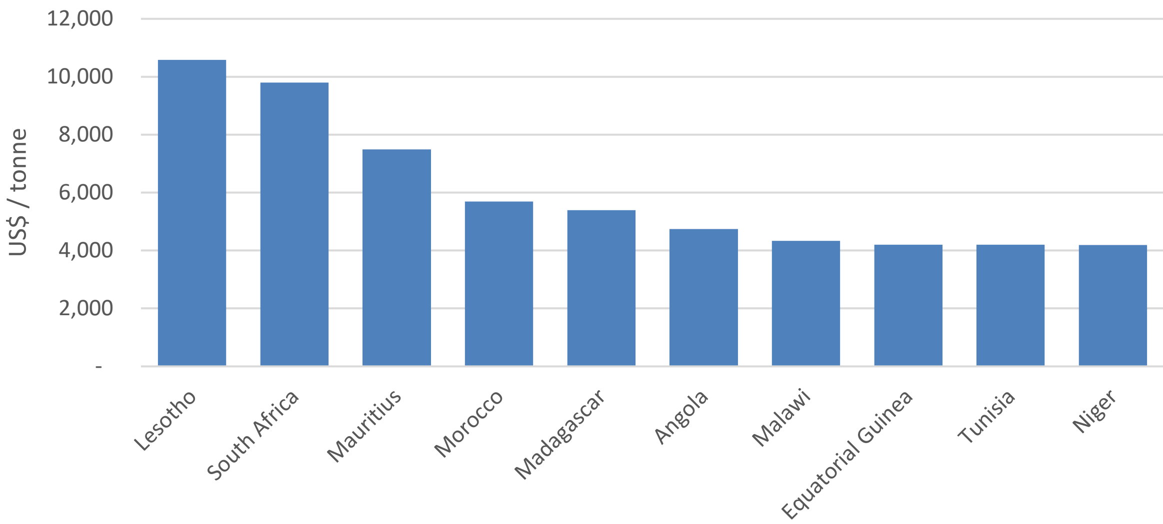
Countries differ in terms of high versus low market value of aquaculture production. To account for these differences, the value per tonne produced was calculated by dividing the value of production by the absolute tonnage (Map 8, Figure 11). The leading countries in value per tonne are Lesotho, South Africa and Mauritius. This can be explained by the cultivation of a number of high-value species for export, including rainbow trout in Lesotho, various marine aquaculture species (i.e., mussels, oysters, and abalone) in South Africa and red drum in Mauritius. Egypt only ranks at 42nd position in terms of value per tonne.

Map 8: Production value per tonne by country (2018)



Cartography: Paula Rothenberger. Data source: FAO (2021)

Figure 10: Top 10 countries by value of aquaculture production by tonne (2018)

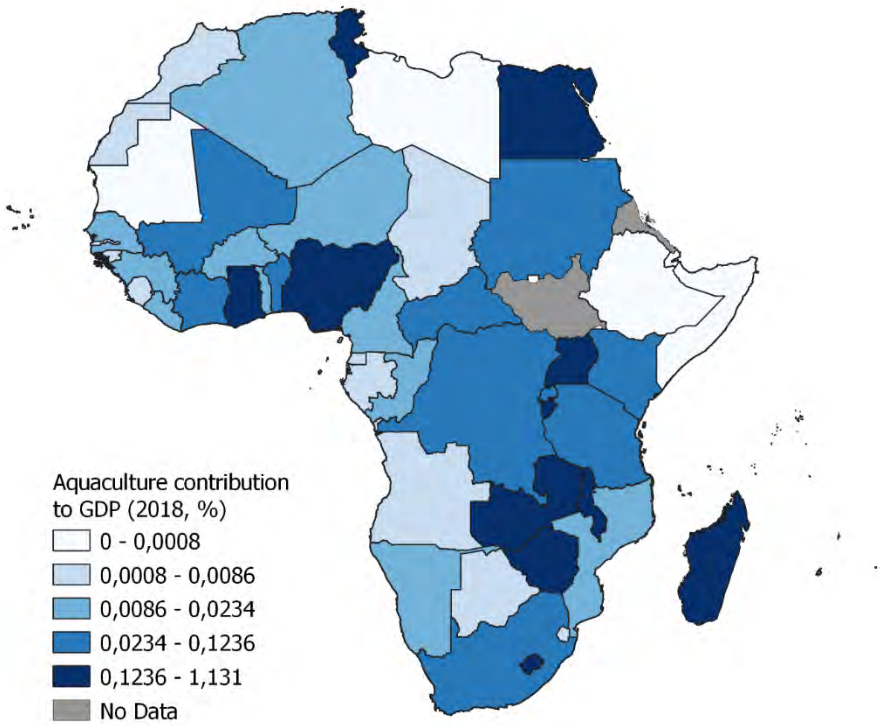


Data source: FAO (2021)

Indicator 9: Contribution of aquaculture to Gross Domestic Product (GDP)

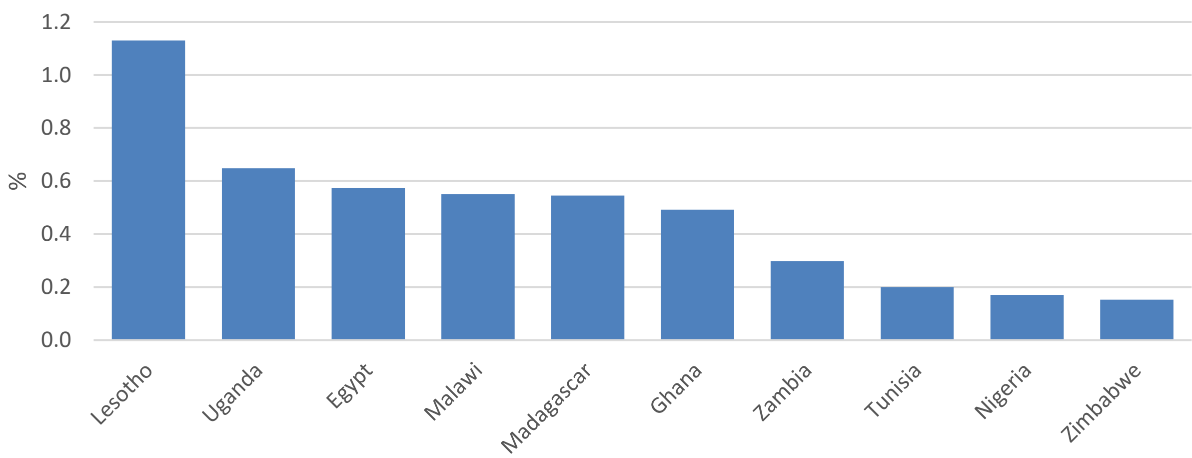
GDP ranges widely in Africa from the lowest levels in the world in impoverished countries like Somalia (GDP of US$ 289 per capita in 2018) and Burundi (GDP of US$ 282 per capita in 2018), to the Seychelles (GDP of US$ 15 810 per capita in 2018) as the only African country that topped the global average of US$ 10,843 per capita in 2018. Assessing the contribution of aquaculture to GDP shows the significant importance of aquaculture in the economy of a country such as Lesotho, where less than two decades ago there was no aquaculture, and where today it is a significant earner of foreign currency (Map 9, Figure 12). Cai et al. (2019) point out that there is much inconsistency in the methods that are used to compare the contribution of aquaculture to GDP. However, in general, the contribution of aquaculture to GDP in Africa remains low compared to other non-African countries.

Map 9: Contribution of aquaculture to GDP (2018)



Cartography: Paula Rothenberger. Data sources: FAO (2021) (production); World Bank (2021) (GDP)

Figure 11: Top 10 countries contribution of aquaculture to national GDP (2018)

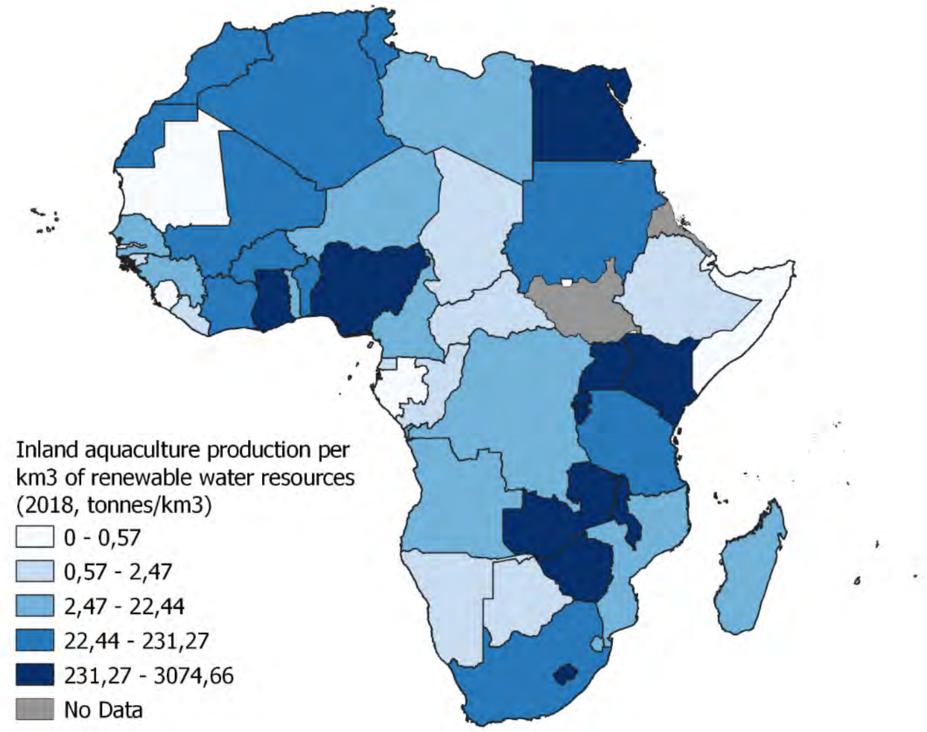


Data sources: FAO (2021) (production); World Bank (2021) (GDP)

Indicator 10: Aquaculture production relative to renewable water resources

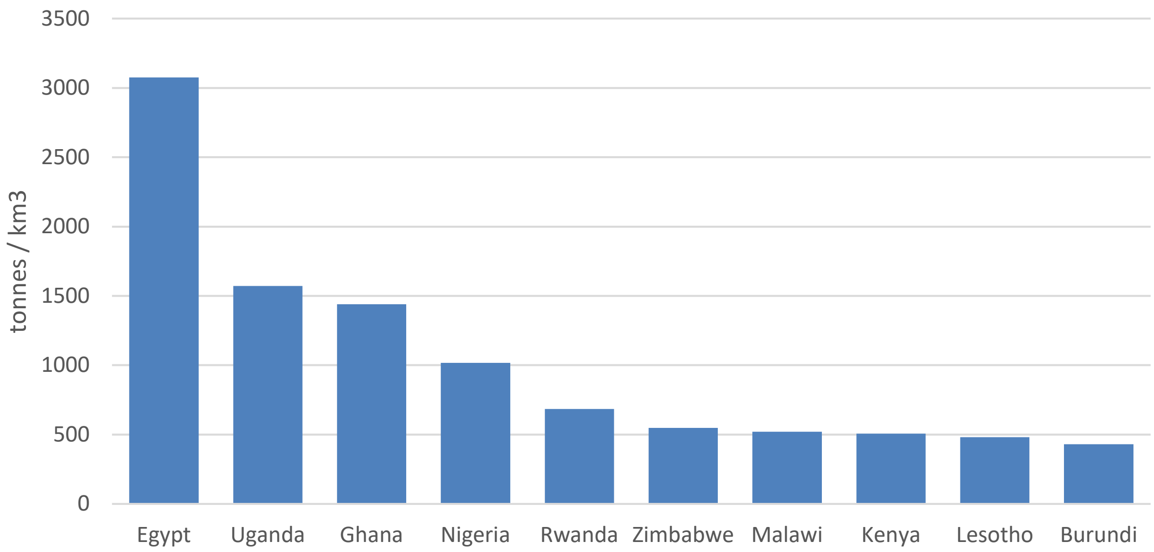
African countries are not equally endowed with the natural resources to support aquaculture development. Aquaculture depends on a suitable climate and, in particular, on the availability of water. Since marine aquaculture development in Africa is still limited, this assessment did not rank marine aquaculture production by factors such as the length of a country's coastline and the size of its exclusive economic zone. The extent of a country's inland or freshwater aquaculture production, as measured by available renewable water resources, provides an indication of how well different countries are using these natural resources for aquaculture development. However, this does not consider how a country's geographic characteristics affect these renewable water resources. The way in which renewable water resources in the Great Lakes along the Rift Valley (e.g., Lake Malawi, Lake Victoria and Tanganyika) accumulate, as well as the impoundment of water in large human-made systems such as Lake Volta (Ghana), Aswan Dam (Egypt), Kariba Dam (Zimbabwe/Zambia) and Katse Dam (Lesotho) are not taken into account in this comparison, although they clearly play a role in facilitating access to water resources for aquaculture development. Egypt leads the ranking in inland aquaculture output related to available renewable water resources (3,075 t/km^3 of water), followed by Uganda (1,572 t/km^3) and Ghana (1,440 t/km^3) (Map 10, Figure 13). Not only does Egypt show a high absolute aquaculture output, but also demonstrates efficient use of available water.

Map 10: Production relative to renewable water resources by country (2018)



Cartography: Paula Rothenberger. Data sources: FAO (2021) (production); FAO (2003) (renewable water resources)

Figure 12: Top 10 countries by aquaculture production related to the availability of renewable water resources (2018)



Data sources: FAO (2021) (production); FAO (2003) (renewable water resources)

5 Country comparisons and implications for policy and research

Country and regional comparisons

The assessment presented in this study shows that ranking the performance of the aquaculture sector in African countries based on absolute production alone provides only a superficial understanding of the sector. Looking at a wider range of aquaculture-related indicators shows that Egypt leads African aquaculture in several of the indicators, but several other African countries appear in the respective top ten rankings that were developed in this assessment.

The Egyptian aquaculture sector contributes the largest share to total national fish supply (Table 3), followed by Lesotho, which has high relative production output from a new trout production sector, but where unreported export volumes do not show that the bulk of trout produced in the country is exported and contributes little to direct local food security. The total fish supply from capture fisheries and aquaculture combined per capita per annum is led by Namibia, Mauritius and Mauritania, mainly due to strong marine capture fisheries output in relatively sparsely populated countries. Overall, island and coastal nations have much higher total fish supply per capita, in some cases well above the global average of 20.5 kg in 2018. The greatest relative shortage of fish per capita was found in Ethiopia, Guinea-Bissau and Sudan.

Table 3: Summary of top 10 African countries for indicators related to fish supply

Rank	Total fish supply per capita (kg)	Contribution of aquaculture to national fish supply (%)	Per capita shortfall to reach av. African per capita fish consumption (kg)
1	Namibia	Egypt	Ethiopia
2	Mauritius	Lesotho	Guinea-Bissau
3	Mauritania	Zimbabwe	Sudan
4	S.Tome & Pr.	Uganda	Botswana
5	Gabon	Sudan	Niger
6	Sierra Leone	Nigeria	Somalia
7	Cote d’Ivoire	Tunisia	Lesotho
8	Egypt	Zambia	Burundi
9	Congo	Ghana	Eswatini
10	Ghana	Madagascar	Zimbabwe

Aquaculture production per capita is highest in Egypt, estimated at 16.2 kg per person per annum (Table 4). This figure is considerably lower in the other African countries, at around 2.6 kg for Ghana in second place and 2.4 kg for Uganda in third place. This shows that aquaculture is still a relatively small contributor to fish and total food supply on the African continent compared to global production. Given the large absolute volume of production, Egypt also ranks first in the value of aquaculture products per capita, followed by Lesotho and Mauritius, where high-value species are farmed for export markets in countries with relatively small populations.

Table 4: Summary of top 10 African countries for indicators related to aquaculture production

Rank	Production volume (tonnes)	CAGR Volume (%)	Production volume per capita (tonnes)	Production value (USD `000)	CAGR Value (%)	Production value per capita (USD)	Production value per tonne (USD)
1	Egypt	Rwanda	Egypt	Egypt	Rwanda	Egypt	Lesotho
2	Nigeria	Burundi	Ghana	Nigeria	Burundi	Lesotho	South Africa
3	Uganda	Lesotho	Uganda	Ghana	Tanzania	Mauritius	Mauritius
4	Ghana	Benin	Tunisia	Uganda	Lesotho	Ghana	Morocco
5	Zambia	Senegal	Zambia	Tunisia	Benin	Tunisia	Madagascar
6	Tunisia	Ghana	Mauritius	South Africa	Senegal	Uganda	Angola
7	Tanzania	Angola	Nigeria	Zambia	Angola	Nigeria	Malawi
8	Kenya	Malawi	Lesotho	Madagascar	Ghana	Zambia	Equ. Guinea
9	Madagascar	Mauritius	Zimbabwe	Tanzania	Niger	Madagascar	Tunisia
10	Zimbabwe	Tunisia	Malawi	Kenya	Malawi	Zimbabwe	Niger

A high-value export product makes Lesotho the leading African country in terms of the aquaculture sector's contribution to GDP, followed by Uganda and Egypt (Table 5). Inland aquaculture production relative to the renewable water resource is led by Egypt, followed by Uganda and Ghana.

Table 5: Summary of top 10 African countries for indicators related to the economic importance of the sector

Rank	Contribution of Aquaculture to GDP (%)	Aquaculture production by renewable water resources (Tonnes / km^3)
1	Lesotho	Egypt
2	Uganda	Uganda
3	Egypt	Ghana
4	Malawi	Nigeria
5	Madagascar	Rwanda
6	Ghana	Zimbabwe
7	Zambia	Malawi
8	Tunisia	Kenya
9	Nigeria	Lesotho
10	Zimbabwe	Burundi

Given the vastness of Africa, a division into regions is recommended. African countries can be clustered into these regions and the leading aquaculture nations can be identified by region.

As outlined in detail above, Egypt dominates aquaculture in **North Africa**. In **East Africa**, Uganda ranks first in absolute production (third in Africa), aquaculture contribution to national fish supply (fourth in Africa), aquaculture contribution to GDP (second in Africa), aquaculture production per capita (third in Africa), aquaculture production by land area (second in Africa) and in the application of renewable water resources to aquaculture production (second in Africa).

In **Southern Africa**, Zambia leads by absolute production volume (fifth in Africa), while South Africa leads in absolute sector value due to the farming of high-value marine species. Lesotho and Zimbabwe feature strongly in the relative contribution of aquaculture to national fish supply, although in Lesotho virtually all farmed fish is exported, resulting in this country's aquaculture sector leading the ranking in Africa in aquaculture's contribution to GDP. Furthermore, Zambia ranks first in aquaculture production output per capita (fifth in Africa), while the value of aquaculture per capita is led by Lesotho (second in Africa). In this region, Malawi leads aquaculture production relative to country size (eight in Africa), while Zimbabwe leads in inland aquaculture relative to renewable water resources (sixth in Africa).

In **West Africa**, absolute aquaculture output is led by Nigeria (second in Africa), followed by Ghana (forth in Africa). The absolute value of the sector is also led by Nigeria (second in Africa), followed by Ghana (third in Africa). The contribution of aquaculture to national fish supply in West Africa is led by Nigeria (sixth in Africa), while Ghana leads in aquaculture's contribution to GDP (sixth in Africa), aquaculture production per capita (second in Africa), and aquaculture value per capita (fourth in Africa). Ghana and Nigeria both lead in production output relative to country size (fourth and fifth in Africa respectively) and inland aquaculture output relative to renewable water resources (third and fourth in Africa respectively).

Aquaculture is not particularly well developed in **Central Africa**, with the Democratic Republic of the Congo leading in absolute production and absolute value of aquaculture, despite only being ranked nineteenth and twenty-first on the continent for these indicators. This is also reflected in the very low contribution of aquaculture to national fish supply and GDP in this region. Concurrently, the per capita supply of fish from aquaculture lags the rest of the continent with Congo leading at 0.122 kg per annum (twenty second in Africa), while Cameroon leads in the per capita aquaculture value (twenty-third in Africa). Nevertheless, and despite the lack of aquaculture development in Central Africa, fish consumption per capita is high, with the island state of São Tomé and Príncipe leading (sixth in Africa), followed by Gabon (fifth in Africa) and Congo (tenth in Africa). The high supply of fish from capture fisheries in these countries could be a contributing factor to the low development of aquaculture.

Implications for policy and research

Support the implementation of existing policies and initiatives

Several aquaculture policies and initiatives at country, regional and continental level are in place to ensure a sustainable increase in aquaculture production in Africa. The African Blue Economy Strategy (ABES) was developed to guide African Union (AU) member states in the development of an inclusive blue economy (AU-IBAR, 2019). The blue economy concept promotes better stewardship of the oceans and "blue" resources through economic, rational and sustainable use. This concept has been incorporated into several continental policies and/or initiatives, such as the AU Agenda 2063, the 2014 Framework and Reform Strategy for Fisheries and Aquaculture in Africa, and the 2014 Africa's Integrated Maritime Strategy (2050 AIMS).

Under the ABES, there are three strategic objectives related to fisheries and aquaculture to be achieved through specific intervention measures. These include: i) Optimizing conservation and sustainable use of fisheries and aquaculture resources while minimizing conflicts with other blue economy sub-themes ii) Achieving the full wealth creation potential of fisheries and the aquaculture sector to optimize contribution to the blue growth and iii) Ensuring sustainable social, economic, environmental and equity outcomes and human rights while protecting natural capital and blue investments (AU-IBAR, 2019).

At the regional level, fisheries and aquaculture policies/initiatives fall under the agricultural policies of the main Regional Economic Communities (RECs). These policies consider all major continental and international strategic frameworks that impact or are impacted by fisheries, such as the AU's New Partnership for Africa's Development Program (NEPAD), the Comprehensive Africa Agricultural Program (CAADP) and the Sustainable Development Goals. Not all RECs have elaborated policies focused on aquaculture; however, they are undergoing a reform process guided by the Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa (PFRS) (AU-IBAR, 2014). With respect to aquaculture, the main policy area in the PFRS is sustainable aquaculture development, which is to be achieved through three strategic actions i.e., i) creation of an enabling environment, ii) establishment of an African Centre of Excellence for Aquaculture and iii) integration of aquaculture strategies and plans into national development plans, particularly into CAADP (AU-IBAR, 2014). In line with the PFRS, the Sustainable Aquaculture Research Networks in Sub-Saharan Africa (SARNISSA) reviewed national aquaculture policies of ten Sub-Saharan countries and made several recommendations aimed at better focused and more effective aquaculture policies. This again underscores the need for aquaculture policy reform.

Empower women in the aquaculture sectors

The important contribution of women in African aquaculture is not sufficiently recognised and not adequately recorded in statistics of fisheries development programs in Africa. Globally, women make up 47 percent of the labour force in aquaculture production, industrial processing, trading, and retail of fresh aquatic products (FAO, 2020a). Similar statistics and further information on the constraints and opportunities women face to effectively engage in the aquaculture sector are missing for Africa.

Moreover, targeted measures are needed to empower women in aquaculture production, processing and marketing. Some African states and development partners are already promoting gender mainstreaming in aquaculture programs that can be built on. Through the African Union Inter-African Bureau for Animal Resources (AU-IBAR), the African Women Fish Processors and Traders Network (AWFISHNET) was established in 2017 as a platform for facilitating gender-responsive policies and practices in the fisheries sector. AWFISHNET brings together female non-state actor fish producers (fish farmers and fishers), fish processors and traders of fish and fish products. It collaborates with strategic partners to drive innovations and technologies, promotes interdisciplinary community dialogues and facilitates advocacy for increased participation of women and youth to generate solutions across the entire fisheries and aquaculture value chain "from field to fork". It protects women and girls' rights involved in the fisheries sector and understands their needs by contributing to i) policy frameworks, ii) research and development, and iii) financing small scale community activities to meet UN Sustainable Development goals of eradicating hunger, enhancing women's economic empowerment, and ensuring gender equality in national development planning. Despite these recent initiatives to increase gender dimensions in the fisheries sector, women continue to be marginalized to access and control resources in many countries (FAO, 2020a).

Reduce the environmental impact of the aquaculture sector

Increase in aquaculture production will lead to resource constraints (Ahmed et al., 2019). The competition for land with agriculture can constrain the expansion of land-based aquaculture enterprises, such as ponds and tanks. In addition, there is indirect land use for growing aquafeeds. Besides limited land availability, increased aquaculture production will also lead to competition for freshwater. As outlined above, aquaculture in Africa is predominantly freshwater (FAO, 2020a). If freshwater aquaculture continues to expand, water limitations due to competition for freshwater with crop production and other uses can occur (UNFCC, 2007). Freshwater is used in land-based systems to maintain pond level and replace water loss through seepage and evaporation. To reduce the pressure created by increased land occupation and enhanced water use, increased intensification and production efficiency of aquaculture production systems for efficient water usage should be implemented while simultaneously decreasing the feed conversion ratios (Mungkung et al., 2014). Switching to mainly marine water systems is not necessarily a solution to address the aforementioned challenges, as a significant share of water in aquaculture is used indirectly through the production of aquafeed (Mungkung et al., 2013).

Another environmental concern relates to water pollution and eutrophication. Expanded aquaculture production can lead to increased pollution and eutrophication due to more extensive use of fertilizers, drugs/antibiotics, wastewater discharges containing nutrients from faeces and feeds, and other chemicals (Waite et al., 2014). In Africa, fed aquaculture is significantly higher than non-fed aquaculture, accounting for over 90% of production annually over the past two decades (FAO, 2020a). Untreated aquaculture wastewater contains high levels of phosphorous and nitrogen from uneaten feeds and waste which can result in chronic levels of organic matter (Cao et al., 2007). This, in turn, negatively affects production as bacterial decomposition of organic matter reduces oxygen levels, eutrophication results in algal blooms, water quality deteriorates and diseases break out (Cao et al., 2007). The impact of aquaculture on the level of eutrophication can be reduced through improvements in technology and management to mitigate water pollution. Improved management practices include the use of settling ponds prior to releasing wastewater, better incorporation of filtration systems, and modern production systems like recirculating aquaculture systems as well as utilizing biofloc technology (Waite et al., 2014).

Implement measures to mitigate and adapt to climate change

Aquaculture can be considered as more vulnerable to climate change compared to capture fisheries as both cultured organisms and infrastructure are affected (Augustyn et al., 2017). Hence, climate change poses a significant threat to aquaculture production (Ahmed et al., 2019). Even though research has been conducted about the impacts of climate change on aquaculture, studies did not specifically focus on effects on African aquaculture. Generally, global warming, ocean acidification, sea level rise, increased intensity and frequency of extreme weather events (floods, drought, and rainfall) are some of the impacts of climate change relevant to the African aquaculture industry, while others are still emerging (Asiedu et al., 2017; Augustyn et al., 2017). These impacts can alone or in combination be responsible for i) ecological changes e.g., changes in primary productivity, emergence of diseases and parasites, algal blooms; ii) physiological changes, impacting the biological processes in the organisms; (iii) operational changes like alternative site or species selection (Augustyn et al., 2017), (iv) limited access to fresh water, (v) limited access to feed ingredients of both marine and terrestrial origin (Dabbadie et al., 2018) and (vi) changes in socio-economic status, e.g. increased poverty and food insecurity for farmers due to events diminishing production (Asiedu et al., 2017).

To build resilience and deal with the impacts of climate change effectively, mitigation and adaptation measures need to be put in place. Mitigation focuses on efforts to manage and enhance processes to control human sources of climate change as well as to remove greenhouse gases from the atmosphere (Victor et al., 2014), while adaptation focuses on building resilience and adaptive capacity for sustainable livelihoods (Bueno & Soto, 2017). Mitigation strategies for aquaculture include sustainable wastewater management, proper feeding practices, use of environmentally friendly practices and technologies, while adaptation measures, as reviewed by Ahmed et al. (2019) and Maulu et al. (2021), include diversification of livelihoods, shifting to different aquaculture species and techniques, integrated aquaculture systems, use of recirculating aquaculture systems and sea food culture. Other environmental sustainability concerns include biotic depletion, especially the use of fishmeal in diets, fish diseases and parasites, habitat destruction and ecological impacts.

Investment and policy priorities for aquaculture sector development in Africa

In order to harness the great potential of the aquaculture sector in Africa for food and nutrition security, several policy recommendations can be made. Drawing on Leape et al. (2021), three main points can be highlighted here:

1. The aquaculture sector and the production of aqua foods must become a central part of government policy making. Thus, blue foods should be considered as part of the food system, rather than as a natural resource.
2. Governments must recognize outputs from aquaculture as a source of nutrients and take measures to enable equitable consumption.
3. Small-scale actors in the fishery and aquaculture sectors in particular need to be strengthened, as they account for the majority of production.

The third point deserves particular attention (Leape et al., 2021). To engage and empower small-scale actors in the aquaculture sector, they need to be involved in all related decision-making and policy processes. In particular women are greatly underrepresented in these processes. In addition, to support environmentally sustainable and productive small-scale aquaculture businesses, investments in technological and human capacities are needed both for expansion and for diversification.

Within this broad framework, additional priorities have been identified to support aquaculture development in Africa (Msangi and Batka, 2015). Given that the aquaculture sector is still nascent in many African countries and regions, production systems that are low in capital intensity and relatively easy to get started may be more suitable (such as tilapia and carp, combined with small, native species also for local consumption). To enable participation in export markets, building capacities to meet quality standards will be essential. Other supportive investments, e.g. in local feed and seed production, as well as infrastructure for transport, electricity and cold chains, are also needed. These investments need to take place within a conducive policy environment under the guidance of a dedicated government office responsible for aquaculture to help coordinate investments, finance, regulations and policy across all relevant sectors.

Simultaneously, it should be noted that policy recommendations need to be adapted to the diverse regions and areas in Africa and tailored approaches must be found due to the different circumstances in different countries. This study assessed an initial set of indicators to inform such tailored approaches. The multi-indicator approach presented here could be expanded to several other variables and comparisons, such as greater consideration of aquaculture performance in relation to climate, geography, other economic indicators as well as indicators related to food security, nutrition and cultural preferences. Comparison with other countries and continents outside of Africa would also provide valuable insights. In addition, strengthening linkages between farmers and researchers/ extension systems and adoption of aquaculture technologies will contribute to growth of the sector.

References

Adedeji, O. B., & Okocha, R. C. (2011) Constraint to aquaculture development in Nigeria and way forward. *Journal of Applied Sciences Research* 7(7), 1133–1140.

Adewumi, A. A. (2015). Aquaculture in Nigeria : Sustainability issues and challenges. *Direct Research Journal of Agriculture and Food Science*, 3(12), 223–231.

Adeleke, B., Robertson-Andersson, D., Moodley, G., & Taylor, S. (2020). Aquaculture in Africa: A Comparative Review of Egypt, Nigeria, and Uganda Vis-À-Vis South Africa. *Reviews in Fisheries Science & Aquaculture*, 1-31.

Agboola, O. J., Yossa, R., & Verreth, J. (2019). Assessment of existing and potential feed resources for improving aquaculture production in selected Asian and African countries. Penang, Malaysia.

Ali, S. E., Jansen, M. D., Mohan, C. V., Delamare-Deboutteville, J., & Charo-Karisa, H. (2020). Key risk factors, farming practices and economic losses associated with tilapia mortality in Egypt. *Aquaculture*, 527(May), 735438. https://doi.org/10.1016/j.aquaculture.2020.735438

Ahmed, N., Thompson, S., & Glaser, M. (2019). Global Aquaculture Productivity, Environmental Sustainability, and Climate Change Adaptability. *Environmental Management*, 63(2), 159–172. https://doi.org/10.1007/s00267-018-1117-3

Asiedu, B., Adetola, J.-O., Odame Kissi, I., & Yildiz, F. (2017). Aquaculture in troubled climate: Farmers' perception of climate change and their adaptation. *Cogent Food & Agriculture*, 3(1), 1296400. https://doi.org/10.1080/23311932.2017.1296400

Augustyn, J., Cockcroft, A., Kerwath, S., Lamberth, S., Githaiga-Mwicigi, J., Pitcher, G., Roberts, M., van der Lingen C. & Auerswald, L. (2017) South Africa. In B.F. Phillips & M. Pérez-Ramírez (eds.) Climate Change Impacts on Fisheries and Aquaculture (Vol. 14, pp. 479–522). Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119154051.ch15

AU-IBAR (2019) Africa Blue Economy Strategy. ISBN: 978-9966-077-36-3.

AU-IBAR (2014) Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa. Retrieved from http://www.au-ibar.org/general-publications%5C

Bondad-Reantaso, M.G. (2007) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. Rome: Food and Agriculture Organization of the United Nations.

Brummett, R. E. (2007). Freshwater fish seed resources and supply: Africa regional synthesis. In M.G. Bondad-Reantaso (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper No. 501. Rome: Food and Agriculture Organization of the United Nations.

Brummett, R. E., & Williams, M. J. (2000). The evolution of aquaculture in African rural and economic development. *Ecological Economics*, 33(2), 193-203.

Brummett, R. E., & Reg N. (1995). Aquaculture for African smallholders. Penang: WorldFish Centre.

Bueno, P. B., & Soto, D. (2017). Adaptation Strategies of the Aquaculture Sector To the Impacts of Climate Change (Vol. 2). Rome: Food and Agriculture Organization of the United Nations.

Cai, J., Huang, H., & Leung, P. (2019). Understanding and measuring the contribution of aquaculture and fisheries to gross domestic product (GDP). FAO Fisheries and Aquaculture Technical Paper, (606), I-69. Rome: Food and Agriculture Organization of the United Nations.

Cao, L., Wang, W., Yang, Y., Yang, C., Yuan, Z., Xiong, S., & Diana, J. (2007) Environmental Impact of Aquaculture and Countermeasures to Aquaculture. Environ*mental Science and Pollution Research-International*, 14(7), 452–462.

Chan, C. Y., Tran, N., Pethiyagoda, S., Crissman, C. C., Sulser, T. B., & Phillips, M. J. (2019) Prospects and challenges of fish for food security in Africa. *Global Food Security*, 20, 17-25.

Dabbadie, L., Aguilar-Manjarrez, J., Beveridge, M. C. M., Bueno, P. B., Ross, L. G., Soto, D., & 1. (2018) Effects of climate change on aquaculture: drivers, impacts and policies. In M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain (eds.) Impacts of climate change on fisheries and aquaculture. Synthesis of current knowledge, adaptation and mitigation options. Rome: Food and Agriculture Organization of the United Nations, pp 449-464.

de Graaf, G., & Garibaldi, L. (2014) The value of African fisheries. FAO Fisheries and Aquaculture Circular No. 1093, Rome: Food and Agriculture Organization of the United Nations.

El-Sayed, A.F.M. (2017) Regional Review on status and trends in aquaculture development in the near east and North Africa – 2015, FAO Fisheries and Aquaculture Circular No. 1088. (Vol. 6). Rome: Food and Agriculture Organization of the United Nations.

El-Sayed, A.F.M. (2014) Value chain analysis of the Egyptian aquaculture feed industry, 44.

FAO (2021) FAO Fishery Statistical Collections, UN Food and Agriculture Organization, https://www.fao.org/fishery/activities/home, accessed 1 December 2021.

FAO (2020a). The State of World Fisheries and Aquaculture 2020. Rome: Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/ca9229en

FAO (2020b). Aquaculture growth potential in Africa. World Aquaculture Performance Indicators (WAPI) (March), 113. Rome: Food and Agriculture Organization of the United Nations.

FAO (2018) FAO Fisheries & Aquaculture - Species Fact Sheets - Sander lucioperca (Linnaeus, 1758). Rome: Food and Agriculture Organization of the United Nations.

FAO (2000) Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000. Rome: Food and Agriculture Organization of the United Nations.

FAO (2003) Review of World Water Resources by Country. Rome: Food and Agriculture Organization of the United Nations.

Hasimuna, O. J., Maulu, S., Monde, C., & Mweemba, M. (2019). Cage aquaculture production in Zambia: Assessment of opportunities and challenges on Lake Kariba, Siavonga district. Egyptian *Journal of Aquatic Research*, 45(3), 281–285. https://doi.org/10.1016/j.ejar.2019.06.007

Hassan, R. M., Hecht, T., De Silva, S. S., & Tacon, A. G. J. (2007). Study and Analyses of Feed and Fertilizers for Sustainable Aquaculture Development. Rome: Food and Agriculture Organization of the United Nations.

Hebisha, H., & Fathi, M. (2014) Small and medium scale aquaculture value chain development in Egypt: Situation analysis and trends. Nairobi: International Livestock Research Institute.

Hollard, J. (2020) Article in SeafoodSource: FAO projects a decade of increased fish consumption, but Africa poses concerns (https://www.seafoodsource.com/news/supply-trade/fao-projects-ten-more-years-of-increased-fish-consumption-but-africa-poses-concerns).

Jamu, D.M. & Ayinla, O.A. (2003) Potential for the development of aquaculture in Africa. NAGA, *WorldFish Center Quarterly,* 26(3), 9–13.

Kajungiro, R. A., Mapenzi, L. L., Nyinondi, C. S., Haldén, A. N., Mmochi, A. J., Chacha, M., … Jan De Koning, D. (2019). The Need of a Structured Tilapia Breeding Program in Tanzania to Enhance Aquaculture Production: A Review. *Tanzania Journal of Science*, 45(3), 355–371.

Leape, J., Micheli, F., Tigchelaar, M., Allison, E. H., Basurto, X., Bennett, A., ... & Wabnitz, C. C. (2021)

The Vital Roles of Blue Foods in the Global Food System. Food Systems Summit Brief Prepared by Research Partners of the Scientific Group for the Food Systems Summit.

Msangi, S. & Batka, M. (2015) The rise of aquaculture: The Role of Fish in Global Food Security. In IFPRI (ed.) 2014-2015 Global Food Policy Report Washington D.C.: International Food Policy Research Institute, pp. 60-72.

Maulu, S., Hasimuna, O. J., Haambiya, L. H., Monde, C., Musuka, C. G., Makorwa, T. H., … Nsekanabo, J. D. (2021) Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations. *Frontiers in Sustainable Food Systems*, 5(March). https://doi.org/10.3389/fsufs.2021.609097

Musinguzi, L., Lugya, J., Rwezawula, P., Kamya, A., Nuwahereza, C., Halafo, J., ... & Ogutu-Ohwayo, R. (2019) The extent of cage aquaculture, adherence to best practices and reflections for sustainable aquaculture on African inland waters. *Journal of Great Lakes Research*, 45(6), 1340-1347.

Mustapha, A. (2020) Improving the quality of aquafeed for an effective food security in small scale African aquaculture. *World Journal of Advanced Research and Reviews*, 7(3), 274–282. https://doi.org/10.30574/wjarr.2020.7.3.0349

Mungkung, R., Phillips, M., Castine, S., Beveridge, M., Chaiyawannakarn, N., Nawapakpilai, S., & Waite, R. (2014) Exploratory analysis of resource demand and the environmental footprint of future aquaculture development using Life Cycle Assessment. Penang: WorldFish Centre.

Mungkung, Rattanawan, Aubin, J., Prihadi, T. H., Slembrouck, J., Van Der Werf, H. M. G., & Legendre, M. (2013) Life cycle assessment for environmentally sustainable aquaculture management: A case study of combined aquaculture systems for carp and tilapia. *Journal of Cleaner Production*, 57(October 2013), 249–256. https://doi.org/10.1016/j.jclepro.2013.05.029.

Mwanja, M., Rutaisire, J., Ondhoro, C., Ddungu, R., & Aruho, C. (2015). Current fish hatchery practises in Uganda: The potential for future investment. *International Journal of Fisheries and Aquatic Studies IJFAS*, 2(4), 224–232.

Satia, P.B. (2017) Regional review on status and trends in aquaculture development in Sub-Saharan Africa - 2010. Rome: Food and Agriculture Organization of the United Nations.

Shaalan, M., El-Mahdy, M., Saleh, M. & El-Matbouli M. (2018) Aquaculture in Egypt: insights on the current trends and future perspectives for sustainable development. *Rev Fish Sci Aquacult*, 26(1):99–110. doi:10.1080/23308249.2017.1358696

Soliman, N.F. (2017) Aquaculture in Egypt under Changing Climate. Alexandria: Alexandria Research Center for Adaptation to Climate Change (ARCA).

Udoh, I.U. & Dickson, B.F. (2017) The Nigerian aqua-feed industry: potentials for commercial feed production. *Nigerian J Fish Aquacult*, 5(2), 86–89.

UNFCC (2007) Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. Bonn: United Nations Framework Convention on Climate Change.

Victor, D.G., Zhou, D., Ahmed, E.H.M., Dadhich, P.K., Olivier, J., Rogner, H.-H., … Yamaguchi, M. (2014). Introductory Chapter. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seybot, … J. C. Minx (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press.

World Bank (2021) World Development Indicators, https://databank.worldbank.org/source/world-development-indicators, accessed 1 December 2021.

Waite, R., Beveridge, M., Castine, S., & Chaiyawannakarn, N. … Phillips, M. (2014) Improving Productivity and Environmental Performance of Aquaculture. Washington D.C.: World Resources Institute.

Annex 1: Data sources

1) Data from the 2003 FAO report Review of World Water Resources by Country was used to list the volume of renewable (i.e., inland) water resources of each African country (https://www.fao.org/3/Y4473E/y4473e.pdf).
2) Data from the World Bank was used to capture the population size and Gross Domestic Product (GDP in USD as constant or real value) from 2011 to 2020 (https://databank.worldbank.org/source/world-development-indicators#).
3) The GDP per capita was calculated by dividing GDP by population size for the years concerned.
4) Data from the FAO's Fishery Statistical Collections: Global Aquaculture Production was used to list the aquaculture output in tonnes and the aquaculture value in USD for inland and marine production systems in each African country from 2011 to 2019 (https://www.fao.org/fishery/statistics/global-aquaculture-production/en). This data was summed to show total aquaculture output and value by nation for the respective years.
5) Data from the FAO's Fishery Statistical Collections: Global Capture Production was used to list the capture fishery output in tonnes for inland and marine systems in each African country from 2011 to 2019 (https://www.fao.org/fishery/statistics/global-capture-production/en). This data was summed to show total capture fishery output by nation for the respective years.
6) Calculations were made to determine the total fish output of each country from 2011 to 2019, which includes capture fisheries output and aquaculture output.
7) Data from the FAO's Fishery Statistical Collections: Global Fish Trade and Processed Products Statistics was used to list the volume of import, export and re-export of seafood from each African country from 2011 to 2018 (https://www.fao.org/fishery/statistics/global-commodities-production/query/en).
8) This data above was subjected to calculation to arrive at a total fish/seafood supply in each African country from 2011 to 2018.
9) From the data above, calculations were made for each of the following parameters for each African country from 2011 to 2018:
    - The contribution of aquaculture to total fish supply as a percentage.
    - The contribution of aquaculture value to GDP as a percentage.
    - Aquaculture production volume per capita.
    - Aquaculture value per capita.
    - Total fish supply per capita.
10) Using information that Hollard (2020) gleamed from the FAO's The State of World Fisheries and Aquaculture 2020, the average fish consumption per capita in Africa in 2018 was set at 10,0 kg per person, compared to the global average of 20,5 kg per annum.
11) Using these African and global averages, the shortfall or surplus in per capita fish supply to reach the average fish consumption per capita for Africa was calculate for each country.
12) Aquaculture output per cubic kilometre of renewable or inland water resources was calculated for each African country.
13) A master spreadsheet was developed to extract the resultant data from each country's database. This master data was used for comparative analysis between African countries.

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