Aquaculture production of North African countries in the year 2030

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Abstract

The main objective of this study is to assess the aquaculture production of North African countries in order to estimate the production up to 2030. The data used in the study is from the Food and Agriculture Organization (FAO) of the United Nations (UN) gathered between 1950 and 2016. The methods employed in the study include a Time Series Analysis (TSA), Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA). According to the results of the time series analysis, the overall production of North Africa is expected to increase by 2030 by 37.7%. Based on the PCA, the production values for Algeria, Morocco and Tunisia fit in PC1, whereas Egypt and Sudan are correlated with PC2. According to the clustering analysis, the aquaculture production characteristics of Algeria, Tunisia and Sudan formed the first cluster since their production characteristics are similar and local. The second cluster included only Morocco, because it is the largest exporter of aquaculture products in the region. Egypt was found as the only member of the third cluster, since it is both a significant producer and the largest importer. Although the aquaculture production in Egypt is very high, it is still insufficient for domestic consumption. For this reason, there is a high rate of imports.

Keywords: Aquaculture, North Africa, Production, Forecast

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Introduction

The North African countries are Algeria, Egypt, Libya, Morocco, Sudan, and Tunisia. Aquaculture is one of the fastest-growing sectors in the North African countries, and it hosts a diverse array of products. Due to the influence of the Sahara Desert, the North African fauna is different from the Middle Eastern fauna (Feidi, 2018). Because of this, species that prefer warm waters grow in northern Africa. Some important species are The Nile tilapia (*Oreochromis niloticus*), Shrimp (*Penaeus vannamei), Mullet (Mugil cephalus), Rainbow Trout (Oncorhynchus mykiss), Sea Bream (Sparus aurata), Common Carp (Cyprinus carpio)*, Catfish (*Clarias gariepinus*), Seabass (*Dicentrarchus labrax*), Mussel (*Mytilus galloprovincialis*), Shrimp (*Penaeus vannamei*), Meager (*Argyrosomus regius*), and Japanese Shrimp (*Penaeus japonicus*) (Burma, 2018). Therefore, it is crucial to look at each country's state of aquaculture production separately to form basic data for future analysis (Fattouh *et al.*, 2010). In Algeria, annual production between 1990-2008 varies between 100 and 130 thousand tonnes, 80% includes of small fish. The fishing industry provides 70,000 jobs, and Algeria produces a wide range of marine and freshwater fish, crustaceans and arthropods in its aquatic ecosystem (Sacchi, 2011).

Both coastal waters and inland water resources are important for fish production in Egypt. Total aquaculture production reached 705,490 tons in 2009 (GAFRD, 2014). 99% of aquaculture production in Egypt produces specialized farms. Egypt has more than 40,000 employees in fisheries sectors at all (Sacchi, 2011). Half of the aquaculture production in Egypt consists of inland aquaculture (Subasinghe *et al.*, 2009; Samy-Kamal, 2015; Kara *et al.*, 2017; Kara *et al.*, 2018; Shaalan *et al.*, 2018; Belhabib *et al.*, 2019). According to the United Nations Food and Agriculture Organization (FAO), Egypt ranked in the top 10 in aquaculture production in 2014 (FAO, 2017).

Agriculture, livestock, and fisheries account for only 3.2% of GDP in Libya. Although Libya has a very long coastline and water potential on the Mediterranean coastline, it lacks inadequate fishing, processing facilities, and ports (Belhabib *et al.*, 2019). Upon FAO's initiative in consideration of this unused potential, cooperation began in 2009. According to the agreement, fisheries were included in the national priorities and economic development objectives (Sacchi, 2011; Belhabib *et al.*, 2019).

The most important and the only river of Sudan is the Nile River. There are many wetlands in Sudan. However, water products cannot be produced enough to meet the domestic consumption in Sudan. This is due to insufficient fishing investments, few fishing fleets and lack of modern fishing boats. (Hafiz, 2010; Abdalla, 2013; Belhabib *et al.*, 2019).

Tunisia is a country with a coastline of 1,300 km. Fisheries and aquaculture have an important role both in the socio-

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economic structure of the country and in its nutrition. The total amount of production in 2014 was 123,326 tonnes. Besides, freshwater fish production in this country is based on rather traditional techniques, and there are efforts to deploy modern methods (Colloca *et al.*, 2017). Training of the fishermen is also part of this investment. The outcomes thereof are expected to become an important economic input, especially for the disadvantaged population groups (Mili *et al.,* 2015; Mili *et al.,* 2016; Colloca *et al.*, 2017).

Morocco is quite well established in aquaculture production and the foremost exporter among the North African countries. The majority of this production is made off-shore, as Morocco's Mediterranean coastline is 512 km in length (Sacchi, 2011; Colloca *et al.,* 2017). Besides these off-shore riches, Morocco has significant opportunities due to its inland water resources. This potential is not used due to the variation of water level between the rainy and the dry seasons. Therefore, although Morocco started growing oysters in the 1950s and planting sea bass and bream in the 1990s, aquaculture ended in 2006 due to changes in water level.

Taken as a whole, aquaculture production from North African countries is important for both the Mediterranean and the world economy (Colloca *et al.*, 2017). Nevertheless, the future trends of the production here have not been studied. In this study, a Time Series Analysis (TSA) (modeling of aquaculture production was performed to estimate the yield until 2030 and to analyze the sustainability of aquaculture in North Africa. Besides, a quantitative approach involving Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) was used to analyze the production, import, and export and consumption data for North African Countries.

Materials and methods

The data used in the study consists of FAO data from 1950 to 2016, collected from the North African countries. The data was examined using the TSA method with EViews9SV software (EViews 9.5 Student Edition Lite) (Liashenko *et al.*, 2017) and using the PCA and HCA methods with IBM SPSS 25 (Saygı, 2020) and the Microsoft Excel software packages. With the help of TSA, the most suitable model was identified to estimate the aquaculture production up to 2030. The year 2030 was taken as a basis to ensure parity with results from the UN, FAO and European Union (EU) for other regions.

For the TSA, first, the mean, median, maximum, minimum and standard deviation of aquaculture production statistics were calculated. Next, normal distribution compliance was checked using the statistical parameters, and the distribution was normalized by clearing off distortions. Following this procedure, the statistical parameters of the normally scattered data were recalculated. After establishing the normal distribution of the data, it is

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necessary to look at some values to determine the most suitable model. These values and expected results are as follows. The determining coefficient (R2) (close to 1), model fit (F test) (largest), Akaike Information Criterion (AIC) (lowest) (Flinn and Midway, 2021) and Durbin-Watson (KP and Sivasubramanian, 2021) values. Accordingly, these values help us find the most suitable model.

PCA reduces a multidimensional data set to a lower-dimension subspace. When the percentage variance of the principal components is greater than 5% (Eigenvalue) or 80% (total variance), these parameters are considered to have significant influence (Jackson, 2005). This is in accordance with Joliffe (1973), which suggests rejecting PCs having eigenvalues less than 0.7. Principal components, known as new sub axes, are multidimensional linear combinations of the original variables in the data set. The first principal component (PC1) corresponds to the large main variant of the data. The second base component (PC2) is principally guided by the second-largest variation of the data and so on (Jolliffe, 2003; Shlens, 2014; Lever *et al.*, 2017).

In addition to PCA, the HCA is used as a classification method to form clusters of countries that have similar correlations with the data set parameters. Hierarchical cluster calculations are based on the similarities within the clusters. The results of cluster analysis are presented as a dendrogram indicating the degree of similarity between the cluster members (Kaufman and Rousseeuw, 2009; Song *et al.*, 2013).

Results

From the time series analysis, for each country, the best model was selected according to the criteria of merit explained in the Methods section. These merits of the best-fit model are listed in Table 1. Below, the estimated aquaculture production by 2030 along with the general trend until that date is presented for each country (Table 2).

For Algeria, a second-order model was selected as the most reliable. This model accounts for 77.7% of aquaculture production. Accordingly, Algeria’s aquaculture production is expected to steadily increase up to 7,741 tonnes by 2030. A second-order model was found to be the best fit for the aquaculture production of Egypt, this model accurately accounts for 99.0% of the data. According to this model, the production of aquaculture by the year 2030 is estimated to reach 3,103,798 tonnes. For the sake of having an estimate of future trends, even if not so reliable, a second-order model was used which accurately accounts for 38.2% of the data. Accordingly, the production of Libian aquaculture production will drop to 2 tonnes, and finish by 2021. Morocco’s production was best fit to a third order (cubic) model. This model accurately calculates 73.0% of aquaculture production. According to this model, aquaculture production will increase up to 21,629 tonnes by 2030.Since Sudan has a 4-year data

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history, it is not sufficient for regression analysis. For this reason, aquaculture production could not be modeled.

Table 1: Descriptive Statistics for North Africa Aquaculture Production (tonnes).

Countries	Number of years	Sum	Mean	Standart Error	Min	Max
Algeria	33	25,247	765.06	148.88	2	2,780
Egypt	66	12,944,035	196,121.74	40,807.29	2,000	1,174,831
Libya	29	2,474	85.31	20.00	0	388
Morocco	49	37,618	767.71	114.86	4	2,793
Sudan	4	10,600	2,650.00	643.56	1,600	4,500
Tunisia	40	101,887	2,547.18	562.86	2	14,425

*Production will end after 2021
** There is insufficient data for this country

Table 2: Parameters of the most appropriate model (R^2, F, AIC and D-W) for North Africa.

Parameter	Model	R^2	F	AIC	D-W	Estimated value of 2030
Algeria	$y = 5.3718x^2 – 99.731x + 562.13$	0.777	31.73	15.386	2.107	7,741
Egypt	$y = 1784.5x^2 - 16125x + 69546$	0.990	1,853.95	23.810	2.169	3,103,798
Libya	$y = -0.0816x^2 + 1.0384x + 41.346$	0.382	7.837	8.607	1.715	*
Morocco	$y = 1.4945x^3 – 56.284x^2 + 529.98x + 758.4$	0.730	63.47	14.540	2.070	21,629
Tunisian	$y = 55.593x^2 – 583.87x + 2772.5$	0.958	224.51	16.500	1.800	50,438

* Production will end after 2021

A consistent linear relationship was found with Tunisian aquaculture production. It made up 95.8% of the data correctly. This model estimates its production to be 50,438 tons by 2030.

As for the PCA, the first two principal components were found sufficient, because they described 88.94% of the sample variability. Note that Libya was not included in this analysis due to a lack of data for the parameters considered in this study.

The other five countries in the North African region were grouped using the 83 variables of the PCA so that the best model with the least number of dimensions defining the data structure could be selected (Table 3). The most significant two functions indicative of the characteristic of the countries and the subsequent scattering of the countries are given in Figure 1. Accordingly, these functions are highly correlated in Algeria, Morocco and Tunisia for PC1 and in Egypt and Sudan for PC2 (Fig. 1). HCA of the aquaculture production in North Africa is pictorially shown as a dendrogram, together with the AU (Approximately Unbiased), p-values and BP (Bootstrap Probability) (Fig. 2). It is seen in this figure that the three main groups are significant at a confidence

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interval of 95% ($p<0.05$). The first discernible cluster comprised Algeria, Tunisia and Sudan. The second included Morocco only, and the third cluster was formed by Egypt alone.

Table 3: Variance values explained by the principal components (Eigenvalues, %of Variance, Cumulative %) for North African countries.

Component	Eigenvalues	% of Variance	Cumulative %
Algeria	3.250	64.995	64.995
Egypt	1.197	23.941	88.936
Morocco	0.313	6.253	95.189
Sudan	0.208	4.161	99.349
Tunisia	0.033	0.651	100.000

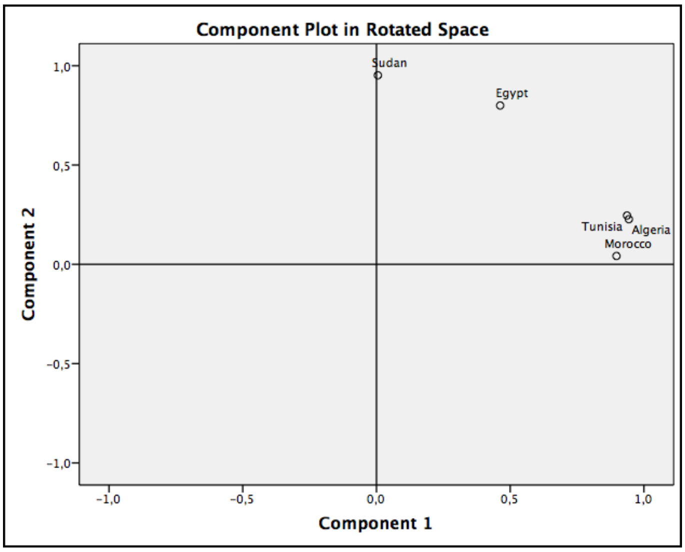

Figure 1: Principal Component Analysis (PCA) for North African Countries (Algeria, Morocco and Tunisia for PC1, and in Egypt and Sudan for PC2).

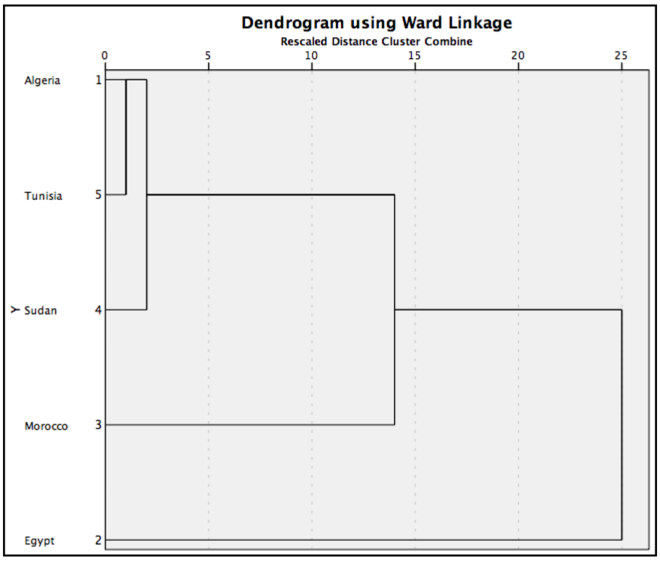

Figure 2: Hierarchical Cluster Analysis (HCA) for North African Countries (Similarity graph of countries).

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Discussion

Based on the results that are detailed in the previous section, first, the results of the time series analysis are discussed for each country. After this, PCA and HCA findings are discussed for each group of countries.

Aquaculture in Algeria has been widely practiced since the 1920s within the borders of Mellah Lake (El Kale). Later, freshwater fisheries were developed, especially from species imported from Hungary (trout *(Oncorhynchus mykiss)* and Common carp (*Cyprinus carpio*)) using western techniques and continental wetlands (Kara, 2012; Colloca *et al.,* 2017; Dinçer, 2018). At present, Algeria's goal is to increase production by 2025 (Kara *et al.,* 2018). From the time series analysis of the present study, it was seen that Algeria's aquaculture production showed a steady increase from 250 tonnes in 1999 to 641 tonnes by 2004. According to the estimation model proposed in this study, Algeria's aquaculture production is expected to be around 7,741 tonnes by 2030 (Belhabib *et al.,* 2019).

A second-order model for Egyptian aquatic products was generated. According to this model, the production of aquaculture is estimated to be around 3,103,798 tonnes (Table 1, Table 2) by 2030. The same total was 1,092,888 tonnes in 2009 (FAO, 2013). This increase is an outcome of the government incentives in most part for the tilapia production sector (Goulding and Kamel, 2013; Samy-Kamal, 2015; Soliman and Yacout, 2016; Colloca *et al.,* 2017; Belhabib *et al.,* 2019).

Libya began producing inland aquaculture in 1970. The 30-year data includes periods of political and military conflicts, and so there have been significant uncertainties impacting all economic indicators, including those for aquaculture production. The already low aquaculture production of 240 tonnes before 2007 fell to 10 tonnes during the internal conflicts (Colloca *et al.,* 2017; Belhabib *et al.*, 2019). However, despite the generally low yield and the drop in aquaculture, the overall aquatic production in Libya thrives over the years, as attested by the 25,014 tonnes of production in 2014 (FAO, 2016). The opposing trends between aquaculture and fish capture are mainly due to public disapproval and higher financial requirements in the former. According to current research, aquaculture production in Libya is expected to end after 2021.

According to FAO data about Morocco, the total aquatic production is 1,409,030 tonnes in 2017, of which 1,407,830 tonnes are obtained from fisheries and only 1,200 tonnes are from aquaculture (FAO, 2019). According to the estimation model developed in the present study, the production of aquaculture in Morocco is expected to increase to 21,629 tonnes by 2030. This trend of increase is seen due to the initiative of the king of Morocco, upon which a strategy was proposed and a development plan for aquaculture was designed. According to this plan, the construction of a multi-purpose

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incubator was proposed along with appropriate training programs (Colloca *et al.*, 2017; Kara *et al.*, 2018; Dinçer 2018; Belhabib *et al.*, 2019).

As stated before, the time series analysis of Sudan's aquaculture was not made due to a lack of sufficient data. However, based on the findings of the previous studies, it is clear that efforts should be made to increase the amount produced to meet local demand and increase exports (Hafız, 2010). The "Southern Sudan Vision 2040: Equality, Justice, Peace and Prosperity for All" adopted by the Council of Ministers of Southern Sudan (Republic of South Sudan (RSS) on January 15, 2010, includes "Aquaculture" among "Priority Programs" (Hafiz, 2010; Sacchi, 2011; Colloca *et al.*, 2017).

The total amount of aquatic production in Tunisia in 2014 is 123,326 tonnes. Of this amount, 112,047 tonnes comes from fisheries and 11,279 tonnes from aquaculture (FAO, 2016; Kara *et al.*, 2018). According to the time series analysis in this study, aquaculture production of Tunisia is expected to reach 50,438 tonnes by 2030. This increase to five-fold capacity is going to come after stable support from the government both financially and legislatively to ensure the growth and sustainability of the sector (Cherif *et al.*, 2011).

PCA study revealed that Morocco, Algeria and Tunusia have similar dynamics in aquaculture production. These countries are geographical neighbors, and their government policies and public acceptance of aquaculture have similar traits. These three countries both meet their internal demands and export to the world market. Sudan and Egypt, on the other hand, have dissimilar traits compared to these prospering three, and the common factor between Sudan and Egypt is their lack of meeting even the internal demand.

As the last step, the HCA study once more confirmed the similarity of Algeria and Tunisia. These two countries can meet their internal demands and have a similar growth pattern. Morocco, which was found similar to these two in the PCA analysis, fell apart from them due to its high export rate of the aquaculture products. Egypt is, on the other hand, is the most distant, which was again figured out in the PCA study. Egypt’s distinct status is both due to its lack of exports and due to incompetency to meet the internal demands.

Conclusion

In conclusion, this study revealed the future trends of aquaculture in North African countries. Although the overall aquaculture production in the region is expected to increase significantly by 2030, if necessary measures are not taken, it will end in Libya by the same date. In this study, the total production of aquatic products in North Africa is estimated to reach 3.0 to 3.3 million tonnes until 2030, hence a 37.7% increase, according to the favorability of the conditions. This finding is similar to that by the World Bank, which foresees 2.9 million tonnes of production from

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the North African region by 2030. Countries should address some important issues in order to increase aquaculture production in North African countries. These can be expressed as follows. The public's adoption of aquaculture needs to be increased. Countries need to solve their financial and legal problems related to fisheries. In addition, States should provide state support to producers. It should be encouraged to increase the diversity of species suitable for the country's own ecosystem. In order for all of these to be done, they need to increase the number of qualified personnel (Callon *et al.*, 2001; Bleu, 2009; Blondel *et al.,* 2010; AllEnvi, 2016; Lacroix *et al.,* 2016; Burma 2018). Also, effective regional monitoring, control and surveillance systems must be in place to ensure conservation and sustainability.

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