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## Review Article

# Climate Smart Aquaculture: A Sustainable Approach to Increasing Fish Production in the Face of Climate Change in Nigeria

### Abstract

As the global population increases, demand for food, most especially protein will increase. Production from fisheries is crucial for food security in the face of current population increase. Despite the reliability on fisheries and aquaculture to supply the animal protein needed by the world population, climate change has significantly reduced production and increase instability in the sector. In order to achieve food security and fisheries development goal, climate smart aquaculture which is an adaptation to climate change and lower emission intensities per output will be necessary. This review therefore discusses climate smart aquaculture as veritable approach to increasing fish production in the face of climate change trend in Nigeria.

A number of changes already evident can be attributed to climate change; drastic change in weather condition, reduction in water levels, changes in hydrological regimes of inland water, heavy wind storm, excessive sunshine, increased incidence of flooding and drought. The effects of these changes have resulted in changes in ocean fish productivity, fish disease infestation and reduction of production from inland and aquaculture systems.

Climate smart adaptation and mitigation strategies has helped to increase the resilience and adaptive capacity of communities and ecosystems, examples of such strategies include adopted strategies in the Niger-Delta region of Nigeria where about 80% of fish farmers were reported to have adopted strategies such as use of tarpaulin/tank ponds during dry weathers, about 70% have adapted by adjusting time of stocking while 60% stocked fish species that can better adapted to climate change impacts. Other adaptations strategies include erection of cover/shades over ponds, digging boreholes/wells to supply water during dry weathers and well-structured drainage system to guide against flooding. Integrated aquaculture is also an important adaptive measure which has gained huge popularity in Nigeria. The use of low carbon producing energy source in the production and processing of product from aquaculture is a viable means to mitigate against climate change, example include the use of gas or electricity rather than charcoal in fish smoking. Aquaculture waste water treatment before discharge is also a good mitigation practice been recently developed.

Climate change will have significant impacts on fisheries and aquaculture in Nigeria. Climate smart aquaculture will respond to these changes by boosting adaptive capacity and resilience both of communities and the ecosystems on which they depend. It is important therefore to ensure adaptation and mitigation in response to climate change so as to safeguard sustainable fish production and food security improvement.

## Introduction

It is now widely accepted that climate change is no longer simply a potential threat, it is unavoidable, this is supported by the evident changes in the present climatic parameters and the vagaries of impact associated with them. The impacts of the accumulation of GHGs in the atmosphere and water relate to the changes in the climatic parameters including gradual changes in water temperature, acidification of water bodies, changes in ocean currents and rising sea levels. These physical changes affect ecological functions within aquatic systems and the frequency, intensity and location of extreme weather events [1]. A range of impacts on fisheries and aquaculture, both direct and indirect, can be expected. In Nigeria, climate change have significant impacts on Nigeria's freshwater and marine aquatic systems and hence on the country's fisheries and aquaculture [2]. The

effects of these change has resulted in elevated water temperatures [3], which affects fish physiological processes, thereby affecting spawning, survival of the juveniles, recruit into the exploitable phase of population, population size, production and yield [4]. The impacts of increased flooding of the freshwater bodies has been negative through erosion of watershed, destruction of fish feeding and breeding habitats, decrease in primary productivity and alteration of the normal resilience of the aquatic systems, or positive in expansion of aquatic habitats for primary and fish productions especially during the dry season [4]. Drought incidence draws down the lakes and reservoirs [5] and gives rise to insufficient flow in the river basins for spawning and primary production thereby affecting fish production. Rise in the water level of the Atlantic ocean lead to intrusion of more salty water into the river delta areas and inundation of the coastal

low-lying areas, thus affecting distribution of both the freshwater and marine fishes as a result of changes in the physical and chemical properties of the waters [6]. The impacts ultimately affect fish population, production and supply, thereby affecting the livelihoods of over 26 million people engaged in the primary and secondary sectors of the fisheries industry, as well as food security of the country (IFC, 2003). Considering the importance of fish sector to Nigeria economy: provision of food supplies, enhancing food security, creation of employment opportunity and income generation, the sector has thus contributed 3-4% of Gross Domestic Product as it occupies a very significant position in the primary sector providing employment for over a million people [7] and contributing about 50% of the animal protein intake of the population, particularly the resource poor (IFC, 2003). Considering the importance of fisheries and aquaculture to food security, it is important to develop strategy of resilience of fisheries and aquaculture sector to the effects of climate change. Also, to ensure the sector delivers sustainable benefits, it is essential to adopt Climate Smart Strategy which is obtainable in Climate Smart Aquaculture (CSA). CSA is aim to support food security taking into account the need for adaptation and the potential for mitigation. CSA is well developed in most of the developed countries of the world; meanwhile, the developing nations including Nigeria have also built various adaptive strategies but which cannot keep pace with the current change being witnessed. In Nigeria, the use of Tapaulin lined pond to reduce water seepage from pond during dry season has helped in all year round fish production; Integrated aquaculture has encouraged increased food production and investment profitability; treatment of fish production waste water before discharge, thereby avoiding pollution of surrounding water bodies; also the use of gas powered smoking kiln has been developed for use to reduce GHG emission. In order to facilitate the process of resiliency, Innovative policies and investment programmes are needed to be developed to help the rural poor respond and adapt to a changing climate. Strategic plan is needed to combat the observable and projected impacts of **climate change** on fisheries and aquaculture in order to protect the livelihoods of the fishing communities and food security.

### Importance of fisheries and aquaculture in Nigeria

Fisheries occupy a unique position in the agricultural sector of the Nigeria economy. It has recorded the fastest growth rate in the agriculture sector as it contributed an estimated 4% to the Nigeria GDP in year 2007, out of the total estimated of 40% being contributed by agriculture [2], this value has increased up to the present figure of 5.4% (Atanda, 2009). It supplies about 50% of the animal protein intake of the country's population especially the resource poor in Nigeria with total consumption of 1.2million metric tonnes (Ahmed and Yusuf, 2014). The total contribution of fisheries to the Nigerian economy is put at 126, 417 billion gross outputs with a capitalization of 78, 530 billion (Faturoti, 2010). According to Raw Materials Research and Development Council (2007), over 10 million people are directly or indirectly engaged in fisheries activities in Nigeria. Food fish has a nutrient profile superior to all terrestrial meats (Beef, pork and chicken among others) being an excellent source of high quality animal protein and highly digestible energy. It is a good source of sulphur and essential amino acids such as lysine, leucine, valine and arginine. It is therefore suitable for supplementing diets of high

carbohydrates contents [8]. From the economic point of view, fishery contributes to provision of employment and has added to economic development through trade for export market.

### Nigeria fisheries production

Nigerians are large fish consumers with a total consumption at more than 1.36 million MT. Fish imports is making up about three fifths (740,000 MT) of the fish supply. Although the contribution of fisheries to the Gross Domestic Product is only 3-4%, it occupies a very significant position in the primary sector providing employment for over a million people and contributing about 50% of the animal protein intake of the population, particularly the resource poor [2]. Furthermore, fisheries in the Nigerian economy show that there is already a demand / supply deficit of over 60%. There is in addition, steady decline in capture fisheries sources, due to normal global trends which are aggravated by specific local disturbances in Nigerian coastal and offshore waters. This scenario has led to a shift in focus to inland water resources especially aquaculture, which efforts have yielded encouraging results in the past few years. Nigeria moved rapidly from a production level of 25,720 m.tons in 2000 to 56,355 m.tons in 2005 to 85,087 million tons [2]. This upward trend is expected to continue and there is a subsisting Government directive on the fisheries administration to among other things; "Review the existing National fisheries Policy and formulate strategies and plans for sustainable fisheries management and development in the country." However, out of the sub-sectoral sources, aquaculture has the greatest and fastest potential for growth.

### Aquaculture production in Nigeria

Aquaculture in Nigeria started in Panyam fish farm in Jos in 1951. Fish production from aquaculture ranges from 15,840 metric tonnes in 1991 to 25,720 mt in the year 2000 and 86,350mt in 2009 [9]. Production varies from 0.5mt/ha in small scale to 10mt/ha in large scale for earthen ponds and this largely depends on level of management intensity [10]. Tilapia and clariid are the most culturable species in Nigeria. The culture of clariid catfish has grown rapidly in the country since 1985 with a total production of 61,916mt valued at US\$86 million in 2007. This has made Nigeria the highest producer of Catfish in Africa [11]. Summary of aquaculture production is presented in [Table 1](#).

### The concept of climate change

Climate change refers to changes in climate brought about by anthropogenic activities and natural variation that alters the composition of the global atmosphere observed over comparable period of time [12]. Climate change has become a new reality of the 21<sup>st</sup> century and has attracted attention in the global corridor of developmental policies and global governance. The on-going climate change and its associated global warming are expected to cause distinctive climate patterns in different climatic zones and will impact negatively on the ecosystem. Climate change brings with it changes in weather patterns that can have serious repercussions on lives and properties; upsetting seasonal cycles, harming ecosystems and water supply, affecting agriculture and food production, causing floods, landslides, drought and famine as weather becomes fierce (Kasperson and Kasperson, 2001).

**Table 1:** Aquaculture Production in Nigeria.

Variables	Value
Inland Water Surface area	1.4 million Hectares
Available Land for Aquaculture	1.7 million Hectares
Existing Pond Area under Water	60,000 hectare
Fish production from aquaculture	85,087 metric tonnes
Estimated Aquaculture Potential	2.5 million tonnes
Average pond Construction rate	
Subsistence pond	500-800kg/ha/yr
Homestead pond	1000-1500kg/ha/yr
Commercial Farms	5000-20,000kg/ha/yr
Recirculatory System	300-400kg/m <sup>3</sup> /production cycle of 4-6 months
Total Fingerling Supply	55.8 million
Commonly cultured species	Tilapia ( <i>Oreochromis niloticus</i> , <i>Clarias</i> spp, <i>Heterobranchus</i> and <i>Carp</i>

**Source:** FDF, (2007) [2].

## Causes of climate change

Climate can change due to natural processes (bio-geographical) and human activities (anthropogenic). The natural processes are the astronomical, the extraterrestrial factors and volcanic eruption. The astronomical factors include the changes in the eccentricity of the earth's orbit, the way the continents is arranged, changes in the obliquity of the plane of ecliptic and changes in orbital procession, while the extra-terrestrial factors are solar radiation quantity and quality among others. On the other hand, the anthropogenic factor in climate change involves human activities that either emit large amount of greenhouse gases (GHG); carbon (IV) oxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), chlorofluorocarbons (CFCs) and nitrous oxide (N<sub>2</sub>O) among others into the atmosphere that depletes the ozone layer or activities that reduce the amount of carbons absorbed from the atmosphere [13]. The human factors that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture (Anyadike, 2009). On the other hand, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution and agricultural practices. Studies of long-termed climate change have however discovered a connection between the concentrations of carbon dioxide which is one of the most important GHG in the atmosphere and mean global temperature. Carbon dioxide is one of the most important gases responsible for the greenhouse effect (Anyadike, 2009). These GHG are able to alter the energy balance of the earth by being able to absorb long wave radiation emitted from the earth's surface. The net results of this process and the re-emission of long wave back to the earth's surface increases the quantity of heat energy in the earth's climatic system. Humans are however the major inducer and sufferers of climate change. In fact, the term 'Climate Change' commonly refers to influences on climate resulting from human practices. This is because increases in the concentration of greenhouse gases in the atmosphere resulting largely from burning of fossil fuels, deforestation and human population increase, have led to an observed and projected warming of the earth, known as the enhanced greenhouse effect. This is why many scientists regard human-caused (anthropogenic) global climate change to be the most important environmental issue of our times [13].

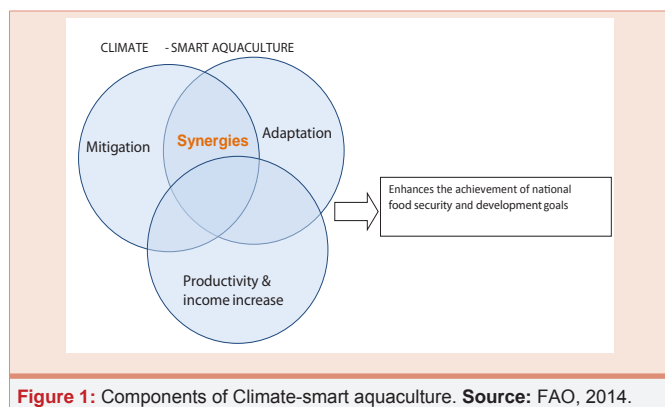
## Impact of climate change on fisheries and aquaculture

The productivity of a fishery is tied to the health and functioning of the ecosystems on which it depends for food, habitat and even seed dispersal [14]. The aquatic ecosystem is however extremely vulnerable to changes in primary production and the manner in which such production is transferred through the aquatic food chain. They are also vulnerable to changes in the physical and chemical parameters of the ecosystems, including temperature, salinity, acidity, and water levels and flows. The physical and chemical parameters are however directly responsible for the productivity and survivability of the biological organism which include fish and aquatic invertebrate. Because marine fish and aquatic invertebrates are cold blooded, their internal temperature varies with their environment. This makes them very sensitive to their environment. When changes do occur fish moves to areas where the external temperature allows them to regain their preferred internal temperature. This "behavioural thermoregulation" [15] is resulting in rapid migrations poleward or into cooler bodies of water [16], corresponding to the poleward shift of climatic zones. Primary productivity is also affected by availability of nutrients in the marine environment, which in turn depends on freshwater run-off and ocean mixing as well as levels of light and temperature. With climate change, primary productivity is predicted to decline at lower latitudes [16], where the majority of the world's small-scale fisheries are located, reducing the productivity of the fisheries. Increased frequency of extreme weather events will also affect the safety of fishers, damage homes, services and infrastructure, particularly in coastal areas [3] and will also damage many coastal ecosystems including mangroves and reefs.

Aquaculture is also exposed to direct and indirect impacts of climatic change, although fewer features and consequences of climate change affect this sector due to a greater level of human control [17]. The vulnerability of aquaculture-based communities is primarily a function of their exposure to extreme weather events, as well as the impact of climate change on the natural resources required to undertake aquaculture, such as quality water, land, seed, feed and energy [18]. However changes in rainfall will cause a spectrum of changes in water availability ranging from droughts to floods and which will reduce water quality. Salinization of groundwater supplies and the movement of saline water further upstream in rivers caused by rising sea levels will threaten inland freshwater aquaculture [3]. Water run-off will also bring in nutrients from sewage or agricultural fertilizers and may cause algal blooms which in turn lead to reduced levels of dissolved oxygen and 'fish kills' [19] and in some cases destruction of facilities as the case of University of Ibadan flooding of their fish production center Plate 1. Rising temperatures similarly reduce levels of dissolved oxygen and increase metabolic rates of fish, leading to increases in fish deaths, declines in production or increases in feed requirements while also increasing the risk and spread of disease [16]. Coastal aquaculture will be exposed to major economic losses from extreme weather events and red tides, the frequency and severity of which are likely to increase [15]. However, not all of the changes will be negative. As sea levels rise, flooding of low lying areas and salinization of groundwater and soil will create ideal conditions for aquaculture in many areas [14], while simultaneously rendering them unsuitable for regular agriculture.



**Plate 1:** Flooded University of Ibadan Fish Farm. Source: Badjeck *et al*, 2012.



**Figure 1:** Components of Climate-smart aquaculture. Source: FAO, 2014.

### Climate smart aquaculture (CSA)

Climate-Smart Aquaculture is aimed to support food security taking into account the need for adaptation and the potential for mitigation. CSA addresses the challenges of building synergies between the related objectives of climate change mitigation, adaptation and productivity and income increase, and minimizing their potential negative trade-offs. Climate-smart aquaculture will require the following:

1. Improving efficiency in the use of natural resources to produce fish and aquatic foods.
2. Maintaining the resilience aquatic systems and the communities that rely on them to allow the sector to continue contributing to sustainable development; and
3. Gaining an understanding of the ways to reduce effectively the vulnerability of those most likely to be negatively impacted by climate change **Figure 1**.

Examples of tactics for attaining CSA objectives in respect to fisheries include: the reduction of excess capacity and the implementation of fishing activities that are linked with improved fisheries management and healthy stocks; increased production efficiency through better integrated systems; improved feeding

and reduced losses from disease in aquaculture; the reduction of postharvest and production losses; and the further development of regional trade. The transition to CSA will need to take place at all levels (individual, business, community, national and regional) and time scales. All stakeholders from private and public sectors will need to be involved in the development of context-specific options to ensure the fisheries and aquaculture sector is climate-smart. To make the transition to CSA, it will be necessary to ensure that the most vulnerable states, production systems, communities and stakeholders have the potential to develop and apply CSA approaches. Markets and trade may help buffer the impact of changes in production that affect food security, consumer prices and supply-demand gaps. However, the implications of climate change impacts and climate change policies on the entire supply and value chain need to be better understood. Appropriate policy measures need to be defined and implemented.

### Adaptation

Adaptation is defined as activities that aim “to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and systems resilience” [20].

#### Adaptation strategies

- Addressing drivers of vulnerability
  - ▶ Diversify sources of household income
  - ▶ Participate in income stabilization programmes
  - ▶ Introduce social protection initiatives
  - ▶ Promote community based risk management measures to face production failure and price of product
  - ▶ Develop innovative risk financing instruments and insurance schemes to reduce climate-related risks
- Building response capacity
  - ▶ Conservation of genetic resources
  - ▶ Implement co-management systems
- Managing climate risk
  - ▶ Disaster risk reduction
  - ▶ Disaster risk management

#### Mitigation strategies

Mitigation promotes efforts to reduce or limit greenhouse gas emissions or to enhance greenhouse gas sequestration” including “technological changes that reduce resource inputs and emissions per unit of output” [20].

Three major options to mitigate climate change are:

- Reducing emission
  - ▶ Adopting improved aquaculture management

- Avoiding or Displacing emission
  - ▶ reducing post-harvest lost
  - ▶ Use of fishing practices that adhere to principles of the code of conduct for responsible fisheries
  - ▶ Removing emission
  - ▶ Replanting mangroves in aquaculture area

### Success of CSA in Nigeria

- At University of Ibadan, Nigeria, Integrated aquaculture has encouraged increased food production and investment profitability [Plate 2](#).
- At CHI Limited, Nigeria, the use of Tarpaulin lined pond has helped in all year round fish production [Plate 3](#).
- Zartech Limited, Nigeria, employs treatment of fish production waste water before discharge, thereby avoiding pollution of surrounding water bodies.
- The use of gas powered smoking kiln has been developed for use at the National Institute for Oceanography and Marine Research as a mitigation strategy towards reducing GHG [Plate 4](#).
- In a research conducted by Thaddeus et al. [21], in Niger-Delta region of Nigeria shows that:
  - ▶ 85% of fish farmers in the region have adopted the use of tarpaulin ponds during dry weather.
  - ▶ 80% have adapted by adjusting time of stocking.
  - ▶ 57.5% adapted by erecting shades over pond.

### Constraint to climate smart aquaculture

- Additional costs in the beginning
- Tenure insecurity in formal and informal tenure systems
- Prohibitive cultural factors, such as community norms and rules
- Scarce information and limited access to extension services
- Limited availability of inputs in local markets, absence of credit/insurance markets.

### Conclusion

Climate change is a serious challenge for the continent of Africa Nigeria inclusive. Impact of climate change limited sustainable production of fisheries and aquaculture. There is need to adopt climate smart approach because it combines adaptation and mitigation in a way that enhance sustainable fisheries production in the face of climatic change. Also, awareness on the climate smart approach is relatively low. Increased awareness on climate smart approaches in fisheries sector have potentials for enhancing food security and sustainable better livelihood for farmers.

### Recommendation

Creation of easily accessed Regional, national and local depositories



**Plate 2:** Integrated Fish Farming in University of Ibadan, an adaptation strategy to climate change impact. Source: Field survey, 2015.



**Plate 3:** Pond lined with Tarpaulin at CHI Limited: an adaptation strategy to water infiltration during dry season. Source: Field survey, 2015.



**Plate 4:** Gas powered fish smoking kiln developed in NIOMR under the sponsorship of WAAPP. **Source:** Ozor and Cynthia, 2010. [6].

for climate and allied data will be necessary so as to increase capacity in information technology and modeling of climate change data. Suitable adaptation and mitigation measures should be site specific to respond to anticipated changes in rainfall and temperature in Nigeria. Models for sustainable fisheries management and aquatic resources conservation would be required for regeneration of fish stocks and ecosystems.

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