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# Profitability and sustainability of modern fish farming in Benin: An on-farm experimental appraisal of two production systems of *Clarias gariepinus*

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**An on-farm experimental appraisal was done to compare the profitability of two production systems of *Clarias gariepinus* in Benin, and to assess the challenges of modern fish farming in West Africa. The results showed that fish farming using above ground tanks (AGT) was not profitable enough to reward production and recover capital costs, should the investments be fully bank loan-funded. At present feed prices, it cannot cost-effectively meet the market demand, and can only provide proteins to producers' households for their own consumption. On the contrary, Lake Water-fed Pond (LWP) fish farming of *Clarias gariepinus* was ten-fold more profitable (profit rate of 57.7%) than AGTs. Although, its profit rate is still far below the potential performance level in the sub-region, it should be promoted among Lake Village cooperatives or young rural entrepreneurs to meet the growing fish demand, especially from Nigeria. Therefore, financial support should be made available to face the high costs of initial investments. Likewise, considering their lower investment costs, AGTs can also be promoted among urban farmers, only if cost-effective local substitutes to imported feeds become available. There is a need to install quality feed production enterprises to promote both fish production systems towards sustainability, food security and economic development.**

**Key words:** Modern fish farming, lake water-fed ponds, above-ground tanks, *Clarias gariepinus*, profitability, sustainability.

## INTRODUCTION

Aquaculture plays a key role in fighting hunger and poverty and promoting rural development. Fresh water and coastal fisheries traditionally provide an important source of food and livelihood for millions of people. However, West Africa is facing the exhaustion of aquatic resources, especially through unsustainable fishing practices. Too much fishing pressure is causing over-exploitation of fish stocks and threatening the contributions they can make to food security and poverty reduction. One quarter of all fish stocks are exploited

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**Table 1.** Low productivity of fish farming in traditional extensive systems in Southern Benin.

| Water surfaces | Annual total production (tons) | Number of fishermen | Annual productivity (ton/fishermen) |
|---|---|---|---|
| Nokoue Lake | 19060.43 | 10452 | 1.82 |
| Porto-Novo Lagoon | 2421.81 | 5537 | 0.44 |
| Oueme Delta | 2461.82 | 10284 | 0.24 |
| Toho Lagoon | 90.03 | 219 | 0.41 |
| West Coast Lagoon | 784.44 | 2658 | 0.30 |
| Sazoué River | 136.38 | 307 | 0.44 |
| Ahémé Lakes Complex* | 858.08 | 9786 | 0.09 |
| Southern Benin | *25812.99* | *39243* | *0.66* |

* Ahémé, Toho, Togbadji and Doukon. Source: Adapted from Sohou et al. (2009).

beyond sustainable levels, and half are fully exploited, with no potential increases in production (African Union, 2003; Sohou et al., 2009).

In Benin, fish farming contributes 11.3% to agricultural GDP (FAO, 1991) but most of this comes from traditional fish harvesting, which is not sustainable due to resource exhaustion practices and biologic water pollution. Indigenous aquaculture is practiced in the departments of Ouémé, Plateau, Mono, Couffo, and Atlantique which represent 43.4% of total population, that is, 4343797 people (INSAE, 2013). Among these, fisheries communities represent about 20%, with average productivity in 1997 of only 0.66 ton of fish per fisherman (Table 1).

Considering the ongoing aquatic resource exhaustion so far, the yield of traditional fisheries today (that is, 20 years later) would be quite ridiculous and explains the growing poverty among these communities. Per capita fish consumption in Benin is now only 12 kg/year (MAEP, 2009), against more than 20 kg/year worldwide (FAO, 2014)[1]. Most of that consumption is fulfilled with importation. Indeed, fish is among the top four imported foods (rice, chicken, fish and milk products), representing altogether 60-100 billion CFA annually (MAEP and MEF, 2010). About 54 000 tons of live or frozen fish worth 22 billion CFA were imported in 2016 (INSAE, 2016)[2], which represents a heavy burden for the country's trade balance.

Hence, there is a need to develop modern fish farming in Benin to meet the country's needs in animal proteins and accelerate poverty reduction through fish exportation to rewarding markets. In that perspective, modern fish farming was among the top priorities in Benin's Strategic Plans for developing the agricultural sector (PSRSA 2010-2015 and PDSA 2016-2021). Various sorts of infrastructure are being promoted, with the aim to develop appropriate fish production systems that would help meet domestic demand more cost-effectively but also supply other West African countries. Fish production raised include African catfish, Tilapia, Captains, etc. The African catfish (*Clarias gariepinus*) is particularly demanded in Nigeria, which is the largest fish consumers in West Africa. The current demand for fish in Nigeria is about four times the level of local production (Ozigbo et al., 2014), and that demand is expected to increase. Hence, Nigeria represents a big market opportunity for modern fish farming in Benin.

Modern fish farming is quite recent in Benin and is practiced by a few retired civil servants. It concerns mostly Catfish (*Clarias gariepinus*), Tilapia (*Oreochromis niloticus*) and Common carp (*Cyprinus carpio*). However, fish importation in Benin represents a huge constraint to competitive domestic modern fish production. The latter can be promoted to meet domestic needs only if it is substantially profitable, considering the relatively high investment costs required. Competition from imported fish can be also faced more efficiently if quality of marketed fish is improved. Upfront of the value chain, there is need to develop adequate production systems and management practices that can be widely adopted by farmers.

This paper compares the financial profitability of two fish production systems - Lake Water-fed Fish Ponds (LWP) and Above Ground Fish Tanks (AGT) - and discusses the conditions of their sustainability for the production of *Clarias gariepinus* in Benin. The development issue at stake is about appropriately directing investment support to fish farmers to develop production systems that are suitable for their investment capacity and locations (peri-urban farms, rural valleys and lakes, rural uplands). Should the government support investments in modern high-productivity infrastructure among rich farmers, or rather promote high-yielding fish production systems among low-to-middle income farmers, or both? In Asia, the implementation of policies to promote aquaculture development, improve governance and capacity factors, as well as institutional arrangements, public-private partnerships and pioneering companies and individuals, were found to create enabling conditions for thriving aquaculture sectors (Williams, 1999).

[1]FAO (2014). http://www.fao.org/news/story/en/item/421871/icode/
[2]INSAE (2016). www.insae-bj.org/?file=files/publications/commerce-ext/...pdf

Whether focus is on export earnings or national food security, any investment decision should be based on the profitability and sustainability of the proposed production systems. Indeed, there is need in Benin to distinguish between rich urban fish farmers, most of which are retired civil servants, and resource poor fishermen that derive most of their livelihoods from lakes and cannot individually afford expensive infrastructure. Yet, the abundant water resources available to the latter require optimal use to enable these communities get out of poverty and improve their livelihoods. Therefore, profitable (productivity-enhancing), environmentally sound and economically affordable production systems should be promoted among them. That's the development perspective of this paper.

## LITERATURE REVIEW

### Fish farming practice in West Africa

FAO (2003) identified three methods of fish farming: extensive system, semi-intensive system and intensive system according to increasing intensity of capital use and decreasing labor use. In West Africa, fish farming is being practiced under traditional/extensive systems since many centuries and is slowly evolving towards semi-intensive systems. In Nigeria, aquaculture dates back to the 1940s at Onikan Experimental farm, South West Lagos and the 160 ha industrial scale fish farm, Middle Belt, Panyam, Jos in 1951. Since then, great expansion has been witnessed in Nigeria's aquaculture industry, graduating from extensive practice to super-intensive systems (Akegbejo-Samsons and Adeoye, 2012). In Uganda, aquaculture was introduced as a non-traditional farm technology in the late 1950's, catfish and Nile tilapia representing today about 95% of total production (Kasozi et al., 2014).

In Benin, traditional fish farming systems are made of in-lake wooden enclosures charged with tree leaves, known as "*Acadja*", for natural reproduction and growth of various fish species that are harvested after a while. Practiced by poor fishing communities since more than a century, they are extensive systems that cannot meet today's growing demand in fish. Capture of immature fishes, river pollution and overall exhaustion of natural resources are also other problems accruing from these systems (Sohou et al., 2009). Alternatively, artisanal, small-scale semi-intensive fish farming with fish ponds are used. Such ponds are made of durable materials and are installed next to the lake, with a moto-pump to ensure water rotation. Fish farming families are also using in-door AGT. AGT can be easily moved from one place to another. In particular, raising *Clarias gariepinus* in AGT requires enough and quality water, and other basic technical conditions. In the practice, only a few among modern fish farmers in West Africa follow these recommendations. As a result, average yields are still far below potential yields.

### Profitability of existing fish farming systems in Africa

Experimental artisanal farming of *Clarias* has been conducted on small plots of 4 – 20 ares[3] near Bangui (Central Africa). Average yields were 180 kg/are in monoculture and 90 kg/are in polyculture with tilapia. Profit rate were about 137 to 164% in monoculture, 88 to 139% in polyculture, and 113% in mixed farms. Basic price and yield assumptions for small 4 are-plots referred to artisanal farming in quasi autonomous situation. Such profitability levels indicate that artisanal fish farming in Bangui neighborhoods could be very profitable if practiced under such conditions. The observed performance levels could be improved with complete mastering of feed procurement (fingerling) and farming method (PROVAC, 2013).

Apparently, there is hope for profitable fish farming business in Bangui surroundings, but practice may see dreams vanish. For example, despite the advancement of aquaculture industry in Nigeria, especially modern fish farming, the industry contributes only 20% to the country's local fish production. Only 25% of aquaculture enterprises in South West Nigeria were profitably operated, while 75% were not (Akegbejo-Samsons and Adeoye, 2012). Fish species raised and the nature of feeds used are critical determinants of fish farming profitability. The results of an experiment on Nile Tilapia (*Oreochromis niloticus* Linnaeus 1757) in Semi Flow through culture system suggested that fish fed with multi-feed were more profitable than those fed with NIOMR feed (Yakubu et al., 2014). Ike and Chuks-Okonta (2014) found that cost of feeds was the most sensitive cost item in aquaculture fish production in Delta State areas of Nigeria. Maximum variable profit would be increased by the adoption of measures that would reduce the price of feeds.

### Modernizing fish farming and prospects for urban fish farming development

The recovery of investment and operational costs and substantial profits to ensure business viability and expansion are critical in a business-oriented choice of fish farming systems. Sautier et al. (2006) reported that fish production increased in many Asian countries during the last decade. However, aquaculture's contribution to food security, nutrition and economic development varies because of unequal capacity and opportunity for modernizing fish farming. The analysis of trade patterns suggests several reasons why this might be the case, including end markets, government support and assistance, ability to react to changing market demands,

[3] 1 are = 100 $m^2$

ability to adopt regulations required for market access (both domestic and international), production scale and investment in infrastructure. Among these reasons, access to inputs, technical know-how and education are the main shortcomings to increasing aquaculture's outputs.

The same reasons hold in West Africa where modern fish farming has remained quite an orphan sub-sector in agricultural development programs, with quite sporadic projects in the framework of hesitant policies. Indeed, depending on the country and donor funds availability, the fisheries sector belongs either to the ministry of agriculture or to the ministry of environment and water, with therefore unstable, unfocused and sometimes contradictory programs. Actually, strong policies to develop private fish farms and facilitate producers' access to reliable markets have not been implemented. Today, massive importation of frozen or canned fish and meat is discouraging domestic production, while there is growing concern about quality and safety of such imported foods (Sautier et al., 2006).

In order to address the above constraints in the framework of NEPAD's Comprehensive African Agricultural Development Program (CAADP), FAO implemented recently in many West African countries, a few big regional fisheries projects (FAO/SFW, 2012)[4]. It is expected that National Agricultural Investment Plans (NAIPs), backed by UEMOA's Regional Agricultural Investment Plan (RAIP) will build on FAO's and other regional projects' experience and support to promote profitable and sustainable modern fish farming in relevant countries. Actually, one should be cautious in choosing a development path. It is likely that combining many types of profitable production systems will be required. Indeed, small and medium-sized farms are typically more efficient producers than large farms in low-income countries and have better consumption and investment patterns for stimulating growth in the non-farm economy. Broad-based agricultural development in turn requires equitable access to land, modern farm inputs, credit and market (IFPRI/ODI, 2005; Heltberg, 1998; Hazell and Roell, 1983; Mellor, 1976). It is also critical to consider the role of women in such a sector like fisheries. In this regard, the lack of market access and inability to secure fair and consistent prices can perpetuate the ongoing cycle of poverty and high risk for the marginalized (especially women), who are unable to plan and save because of highly volatile market. Innovation is therefore key to ensuring agro-enterprises can adapt to changing market conditions and remain competitive (Collett and Gale, 2009).

In Benin, while reflections are underway about a potential support to fishermen cooperatives to install modern fish ponds or basins for fish farming in many rural fisheries communities, the use of AGT by urban families to produce fish either for their own consumption or for sale is also being explored. Several types of AGT made of various sorts of materials (wood, zing, glass, Plexiglas, plastic, etc.) are available today in the market. However, the conditions of their profitability and sustainability are not yet sufficiently documented. PROVAC (2014) reported that the choice of a type of AGT infrastructure is determined by farmers' financial capacity, kind of fish enterprise envisaged (fingerling production and table food market production), and technical knowledge. In fingerling production, operators raise fingerling for sale to commercial fish farmers and wholesalers. While in table food market production, operators grow fingerlings to table market size for restaurants, food stores, farmers and markets, etc.

## MATERIALS AND METHODS

Data were obtained from field practice, an on-farm case study in 2012 in the framework of a technical partnership between the Faculty of Agronomic Sciences/University of Abomey-Calavi and private farms in Benin.

### Overview of the case study

*Clarias gariepinus* husbandry was conducted in 2010 on a 5 ha private fish farm which was created in 1984. The farm is located in the village of Djèrègbé, Sèmè-Kpodji District, near Nigeria border. That district lies mostly on hydromorphic soils resulting from leaching and sedimentation, and therefore suitable for fisheries. The two types of infrastructures –LWP and AGT – form the basis for yields, returns and costs comparison in the present case study. They were supplied with fish seeds (fingerlings) the same day, so that feed quantities and other production costs could be estimated according to the farm's practices[5]. The technical itinerary of Clarias raising included: preparation of breeding infrastructures (cleaning/dirty water removal from enclosure or getting AGT ready), fingerlings input to infrastructure, and control fishing every 17 days after fingerlings supply. Ration was provided as specified in fish feeding calendar, in relation with growth indicators.

Fishes were nourished with imported feed (COPPENS) in relation with weights recorded at control fishing (Table 2). Feeding frequency was twice per day (morning and afternoon). Ration was calculated according to the formula below:

Biomass (Kg) = Number of fishes × average weight
Quantity of feed = Biomass (kg) × Nourishing rate (% weight/day)

[4] In the broad perspective of preserving and adding value to water resources in West Africa, FAO Sub-regional Office for West Africa (SFW) supported the implementation of sub-regional aquaculture projects to develop sustainable fisheries through Regional cooperation. The lack of improved fish seed infrastructure to increase fishing productivity constitutes a major constraint to sustainable fisheries' development. SFW supported the installation of Fish Aggregating Devices (FADs) in 5 Islands of Cape Verde, the implementation in Ghana of the Tilapia breeding program with the 7th Generation of 'Akossombo strain' to benefit hatcheries and farmers shortly, and Trainings in Nigeria on best business practices from pond construction to marketing (FAO/SFW 2012).

[5] The farm is a reference farm, as it is a pilot site for Ministry of Agriculture's PROVAC training program for fish producers. The promotor got the appropriate training in fish farming techniques in 2010 from the PROVAC project of Ministry of Agriculture, and a financial support in 2011.

**Table 2.** Feeding ration of *Clarias gariepinus* according to fish weight.

| Weight (g) | Nourishing rate (% weight/day) | Weight (g) | Nourishing rate (% weight/day) |
|---|---|---|---|
| 10 | 5.9 | 300 | 2.5 |
| 30 | 4.8 | 400 | 2.2 |
| 50 | 4.3 | 500 | 1.9 |
| 100 | 3.6 | 600 | 1.6 |
| 200 | 2.9 | | |

Source: The on-farm case study.

**Method of assessing profitability and sustainability**

Partial production budget and complete operating farm account were used on data from a modern private fish farm. Partial budget of each system was prepared using variable costs (inputs; specific materials that depreciate and exhaust completely in less than one year; and wage of occasional labor) and specific fixed costs (depreciation of infrastructure–machinery and heavy equipment; salaries of permanent labor; and overheads–taxes, rents, electricity, etc.). Complete farm budget or operating account considers the addition of general costs including depreciation of infrastructure and production costs that are common to both systems.

In that farm account, the budget lines include: Gross return which is quantity produced times selling price. Production costs include variable and fixed costs as explained above. The gross margin is gross return minus variable costs. Unit or per kg gross margin is gross margin divided by quantity of fish produced. It allows the comparison of production systems rearing a same fish species. The net margin is gross return minus total production costs. Unit net margin or per kg net margin is net margin divided by quantity of fish produced. It allows the comparison of production systems raising different fish species. The formula below was used:

Gross return = Quantity of fish produced (kg) x unit price of fish; variable costs = inputs (feed) + labor + small tools (material lasting no more than one year); fixed costs = depreciation of equipment (infrastructure + material lasting more than one year) + salaries of permanent labor + overheads; gross margin = gross return – variable costs; net return (NR) = gross return – total costs (TC); profit rate (%) = 100 × NR/TC

Overall, the main indicators of the financial performance of each production system include the per kg gross margin, per kg net return, and mostly the profit rate. The most critical and ubiquitous indicator of financial profitability is the profit rate. It is the net return (or profit) (NR) divided by total production costs (TC). It is usually expressed in percentage (%) of total costs and enables the comparison of production systems using either the same or different fish species, or different farms using different combinations of fish species.

## RESULTS AND DISCUSSION

### Comparison of LWP and AGT's fish farming profitability

The results in Table 3 show that unit gross margin (FCFA/kg) from *Clarias* production in LWP is 31.1% greater than in AGT. However, it is worth recalling that the two types of infrastructure do not give the same possibility for fish production, that is, the amount to be harvested at a time which depends on the quantity of fingerlings supplied and feeding sources. In the ponds (LWP), fishes feed themselves with living organisms (animal and vegetal planktons) available in the river water, in addition to the feed supplied by the fish farmer. In the case of AGT, only the feed is available to them, while water is artificially supplied with usually high oxygenation constraints related to water rotation, oxygen equipment and power supply. In contrary to LWP, fishes raised in AGT also use their energy not only for growth but also for breathing, while their mobility is restricted, thereby limiting their growth and weight gain.

### Discussion on the financial profitability of Clarias fish farming

The net return per kg obtained from farming with LWP is higher than with AGT. Likewise, the profit rate obtained with LWP is 57.67%, which is ten-fold that with AGT (Table 3). The profit rate in the latter case is by far lower than the 20% interest rate charged on loans from commercial banks in Benin. This indicates that only LWP fish farming provides an adequate cost recovery and a substantial capital remuneration.

The message from these results is that modern is not always profitable, as the theory of industrialization would pretend. Considering the growing demand for fish in Benin and Nigeria, and the contrasting high level of poverty and malnutrition among fisheries communities in Benin (Sohou et al., 2009), the above finding of the study provides an argument for promoting investment support to these communities for Clarias fish farming in ponds (LWP) along lakes. Indeed, such an action will enable the production of large quantities of fish to meet domestic needs in quality protein and for sale, especially in Nigeria where this fish species is particularly appreciated, and to break the vicious circle of huge fish imports.

However, although Clarias farming in LWP is more profitable than in AGT, the latter may be worth a promotion if, and only if, local substitutes to imported feed become available. Indeed, feeds represented 72-74 and

**Table 3.** Complete budget of 6-month LWP and AGT farming of *C. gariepinus.*

| Items | AGT | LWP |
|---|---|---|
| Quantity of fish (kg) | 36 | 720 |
| Yield (kg/are) | | 360 |
| Gross Return (FCFA) | 54000 | 1080000 |
| Variable costs (FCFA) | 36250 | 614500 |
| Inputs | 35250 | 579500 |
| Labour | | 35000 |
| Small tools | 1000 | |
| Fixed costs | 14834 | 70500 |
| Gross margin (FCFA) | 17750 | 465500 |
| Gross margin per kg (FCFA) | 493.05 | 646.52 |
| Net return or profit* (FCFA) | 2916 | 395000 |
| Net return per kg (FCFA) | 81 | 549 |
| Profit rate** (%) | 5.70 | 57.66 |

*In normal business, capital cost (interest on bank loans and loan administration costs), taxes and other fiscal dues should be deducted from the net return to get the profit. **Profit rate = 100*(profit/total cost); Source: The experiment.

48-58% of total production cost, respectively in monoculture and polyculture in Bangui neighborhoods[6]. Ike and Chuks-Okonta (2014) found that they weigh 79% in total cost in Burutu and Warri South areas of Delta State, Nigeria. In the current case, imported feeds accounted for 50% of total cost, yet with profit rate (57.7%) far lower than the 87.6-163.6% observed in Bangui several years ago[7]. Kasozi et al. (2014) also found a comparable profit rate of 69% in West Nile agroecological zone of Uganda. Alternatively, substantial profits could be derived also from AGT fish farming when local feeds combining animal husbandry by-products and living organisms such as tadpole are used (FAO, 1991). This type of fish farming, which requires less investment than LWP, would be then profitable for small farmers and lead to artisanal fish farming development. Moreover, considering the easy mobility and low space fitting of AGT, its dissemination among urban farm households can therefore be envisaged for addressing unemployment among the youth. Yet, it is inappropriate for large-scale commercial production because of dis-economies of scale (PROVAC, 2013, 2014).

## Conclusion

The paper aimed to shed a first light on fish farming profitability in Benin, with the aim of appropriately directing investment support towards more suitable fish production systems depending on investment capacity and locations (urban, rural valleys, lakes and rural upland) of targeted farmers. The experimental assessment of Clarias' production systems in Benin revealed that lake water-fed pond fish farming was very profitable and may be promoted among village fishermen's cooperatives or young rural entrepreneurs. Considering that fishermen's cooperatives are not yet very well developed, NGOs and the government should provide the dedicated group management training and financial support to fishermen to enable them face the high initial investment costs of ponds' installation. On the other hand, AGT fish farming was by far less profitable due to high costs of imported feeds and electricity. However, small urban farm households may be advised to use it for meeting their family needs in proteins. AGT is more affordable to medium-scale fish farmers and may still be promoted for commercial fish production when cost-effective local substitutes to imported feeds become available. There is a need to install quality feed production enterprises to promote both fish production systems towards sustainability, food security and economic development. The study confirms that modernizing fish farming is not only a matter of modern infrastructure but also of feed quality depending on feed type (natural aquatic or non-aquatic organisms vs. manufactured feed, nutritional density) and feed affordability depending on sources (locally produced vs. imported).

However, the study's limitation points to the fact that the results would have had stronger significance if they are derived from a sample of fishermen using both types of infrastructure. Further research is therefore needed in that respect, as well as on farmers' perceptions of the

[6] FAO Archive on the breeding of African catfish *Clarias gariepinus*.
[7] FAO Archive on the breeding of African catfish *Clarias gariepinus*.

proposed technologies.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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