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Economic Evaluation of Using Different Water Sources in the culture of African Catfish (*Clarias gariepinus*; Burchell, 1822) at Ediba-Qua, Calabar, Cross River State, Nigeria

***[1]AYIM, EM; [2]ISAH, MH; [3]UKOREBI, EA**

*[*1]Department of Animal and Environmental Biology, University of Cross River State, Calabar, Nigeria*
[2]Department of Biological Science, Faculty of Sciences, Confluence University of Science and Technology, Osara, Kogi State, Nigeria
[3]Department of Microbiology, Faculty of Biological Sciences, University of Calabar, P.M.B 1115, Calabar, Nigeria

**Corresponding Author Email: ayimmonfung@yahoo.com*
**ORCID: 0009-0006-1292-4704*
**Tel: +2348039713658*

***Co-Authors Email:** isahmh@custech.edu.ng; eaukorebi68@gmail.com*

ABSTRACT: The objective of this paper is to evaluate the economic use of different water sources in the culture of the African Catfish (*Clarias gariepinus;* Burchell 1822*)* at Ediba-Qua, Calabar, Cross River State, Nigeria using standard appropriate techniques. Results obtained showed that cost of feeding increased significantly at ($p < 0.05$) with growth rate and weight gain in fish reared in borehole water having the highest cost (₦ 21617.86 ± 31.77) and least in rainwater (₦ 13635.93 ± 48.16). Profit index was highest in *C. gariepinus* reared in borehole water (16.99 ± 0.70), and least in stream water (15.74 ± 0.42) indicating that borehole water is the best water source for *C. gariepinus* with regards to profitability. This study has shown that fish farmers and fish intending farmers who are challenged by borehole water supply for fish culture can alternatively harvest rainwater or collect stream water to rear fish that could be utilized at a subsistent level.

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Water resources are essential to many different sectors of the economy, including fisheries and aquaculture, livestock production, agriculture, forestry, hydropower generation, industrial activities, and other creative endeavours. Water is a valuable natural resource that is a major component of ecosystems and can be obtained from rivers, lakes, precipitation, glaciers, ground water, etc. World Economic Forum (WEF, 2014). In fish culture, water is known to be a limiting factor and the final site selection consideration is usually based on water source (Mukami, 2010). Some of the most common sources of water for aquaculture are groundwater, municipal water, wells, rivers, springs and lakes (Bhatnagar and Devi, 2019). Of all the sources mentioned above, springs and wells are considered to be consistent in terms of high quality (Mukami, 2010). However, Rainwater is considered to be the purest form of naturally occurring water (Chris, 2018). The process of rain formation and rain fall is considered to be produced by a kind of natural distillation (Chris, 2018). Rain water contains several dissolved gases such as carbon dioxide, nitrogen dioxide, sulphur dioxide, ammonia, aerosols or fine particulate materials etc. from the atmosphere (Asthana, 2003). Rain water composition is a

**Corresponding Author Email: ayimmonfung@yahoo.com*
**ORCID: 0009-0006-1292-4704*
**Tel: +2348039713658*

reflection of the atmospheric composition through which it falls.

Aquaculture has now become the surest strategy for a sustainable fish production to curb food insecurity without any serious or negative footprint on the environment (Friend and Funge-Smith, 2012; UNFTP, 2012). In Nigeria, fish is consumed because it is one of the cheapest protein source and is also rich in both macro and micro nutrients required for good health and growth (Ajang *et al*., 2018). Catches from capture based fisheries has gradually declined due to poor management practices, indicating the need for other means of fish production to meet the demand. Aquaculture now becomes the only reliable way to produce fish without any undesirable influence on the environment and capture based fisheries (Ayim *et al.*, 2018).

The culture of the African catfish (*C. gariepinus*) has gained popularity in Nigeria due to its table size, good taste, meat quality and additionally, its high acceptability of locally formulated diets couples with its ability to withstand stress. According to Eyo *et al.*, (2014), most catfish farmers in Nigeria are faced with numerous challenges such as cost of imported foreign feed, scarcity of fast growing fingerlings, lack of credit facilities for expansion, lack of processing and storage facilities, lack of steady market for table size fish etc. However, most of these challenges have been addressed but one of the major problem that is limiting fish production in Nigeria that has been ignored is access to good quality water supply especially in rural areas with little or no developmental impact by government. For instance, in Cross River State, some farmers are presently using municipal water supply for fish production because of the high demand of fish protein. Municipal water which is properly treated for public utilization has some levels of chlorine and other chemical constituents which may be detrimental to fish. Fish production through aquaculture in Nigeria is on the increase (Ajang *et al.,* 2018), though the pace of this development is limited by several challenges such as lack of good quality water that will enhance optimal growth and good health of the cultured fish especially in some rural communities where they lack access to good water. Farmers and intending farmers in such areas are searching for alternative water source that will be economical for fish production without negative impact on fish growth and well-being.

Hence, the objective of this paper is to evaluate the economic use of different water sources in the culture of the African Catfish (*Clarias gariepinus*; Burchell, 1822) at Ediba-Qua, Calabar, Cross River State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area: The research was carried out at Ediba Qua, Calabar Municipal Council which is located at the Southern part of Cross River State, Nigeria and lying between longitude 8.32°E, latitude 4.95°N (Figure 1).

Sources of water for the experiment: Water used for the experiment was collected from three different sources namely borehole water, rainwater and stream water. Rainwater was collected from rainfall through the roof gutter and stored in a Gee Pee tanks, borehole water was collected from a borehole and stream water was collected from Uwanse stream located along longitude 8.32°E, latitude 4.95°N (Figure 1) in Calabar, Cross River State. The three water sources were labelled Source A (Stream water), Source B (Borehole water) and Source C (Rainwater).

Experimental fish: A total of two hundred and twenty five (225) healthy *C. gariepinus* fingerlings having a bulk weight and average length of 254.22 ± 0.85 g and 11.50 ± 0.24 cm respectively were purchased from the University of Calabar fish farm and transported to the study area in a 50 liters water storage plastic can.

Experimental design: The experiment was conducted in three water treatments (Treatment A, Treatment B and Treatment C) using 9 tarpaulin units measuring one cubic meter (1 m^3) to aid replication. The 9 tarpaulin units were labelled A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2 and C_3. 25 fish were stocked in each unit and acclimated for fourteen days prior to the beginning of the experiment. During the acclimation period, the experimental fish was fed to satiation twice daily with Coppens feed. At the commencement of the experiment, the fish was starved for 24 hours. At the end of the 24-hour starvation period, the initial body weight and initial total length of the fish in each tarpaulin unit were measured with Metlar MT-5000D electronic weighing balance to the nearest gram and measuring board to the nearest 0.1 cm (Eyo and Ekanem, 2011, Ajang *et al*., 2018). Fish in tarpaulin units A_1, A_2 and A_3 were reared using stream water, fish in tarpaulin units B_1, B_2 and B_3 were reared using borehole water while fish in tarpaulin units C_1, C_2 and C_3 were reared using rainwater. Feeding was done at 3 % of their body weight twice daily by 8.00 am and 4.00 pm. Body parameters of fishes in all the tarpaulin units such as total length (TL) and total weight (TW) were measured every 14 days.

Economic analysis of rearing C. gariepinus from different water sources Economic evaluation of rearing *C, gariepinus* from dissimilar water sources was performed based on the present-day price of

Coppens feed in Nigeria, kilogram of *C. gariepinus* and the cost of procuring water from different water sources during the period of the study.

The financial assessments were determined by New (1989) as presented in equations 1, 2, 3 and 4 respectively

.**Let:** ICA = Investment Cost analysis, C_f = Cost of feeding, C_S =Cost of fingerlings stocked C_W = Cost of water procurement, NPV= Net production value, W = Weight gain, S = Survival, BCR = Benefit cost Ratio, PI = Profit Index
Thus, we have:

$$ICA = C_f + C_S + C_W \quad (1)$$

$$PI = \frac{NPV}{C_f + C_W} \quad (2)$$

$$NPV = W \times S \times C_f + C_W \quad (3)$$

$$BCR = \frac{NPV}{ICA} \quad (4)$$

Statistical analysis: The data collected were subjected to a one way analysis of variance (ANOVA) to test for significant variations using a predictive analytical software program (version 19.0). Probability of P > 0.05 were not considered significant. Also, data were presented as means and standard error of the triplicate units.

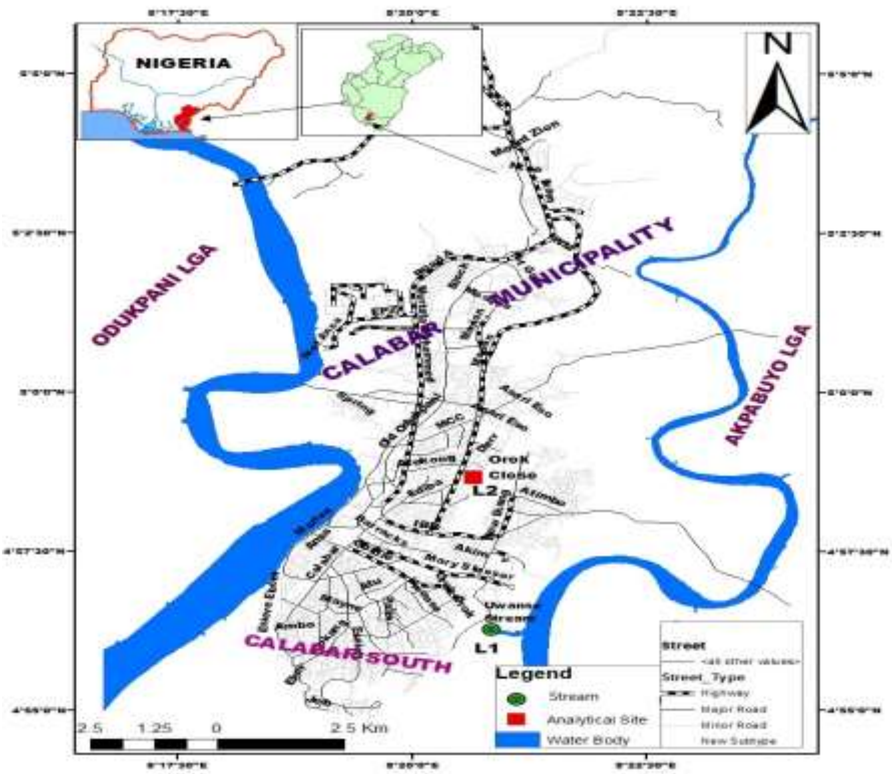

Fig. 1*:* Map of the Study Area
(Source: Ukorebi, 2021)

RSULTS AND DISCUSSION

Water Usage and financial evaluation of the cost of water from the three sources: Water usage (Table 1) for the three water sources was evaluated in three phases. Phase 1 was the period of stocking (Day 0) to Day 20, phase 2 was from Day 24 to Day 48 and phase 3 was from Day 52 to Day 136. The same quantity of water was used from the three water sources from Day 0 to Day 136. In phase 1 (Day 0 – Day 20), 200 ± 0.00 liters of water was used. In phase 2 (Day 24 – Day 48), 240 ± 0.00 liters of water was used and in phase 3 (Day 52 – Day 136), 280 ± 0.00 liters of water was used. At the end of the study, a total of 9040 ± 0.00 liters of water was used for stream water, borehole water and rainwater.

Table 1: Water Usage of *C. gariepinus* reared in different water sources

Exchange Period	Stream water (liters)	Borehole water (liters)	Rainwater (liters)
Day 0	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 4	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 8	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 12	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 16	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 20	200 ± 0.00	200 ± 0.00	200 ± 0.00
Day 24	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 28	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 32	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 36	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 40	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 44	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 48	240 ± 0.00	240 ± 0.00	240 ± 0.00
Day 52	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 56	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 60	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 64	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 68	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 72	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 76	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 80	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 84	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 88	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 92	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 96	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 100	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 104	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 108	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 112	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 116	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 120	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 124	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 128	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 132	280 ± 0.00	280 ± 0.00	280 ± 0.00
Day 136	280 ± 0.00	280 ± 0.00	280 ± 0.00
Total	9040 ± 0.00	9040 ± 0.00	9040 ± 0.00

Table 2: Financial evaluation of the cost of water from the three sources throughout the experimental period (N)

Exchange Period	Stream water (₦)	Borehole water (₦)	Rainwater (₦)
Day 0	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 4	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 8	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 12	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 16	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 20	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 24	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 28	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 32	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 36	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 40	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 44	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 48	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 52	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 56	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 60	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 64	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 68	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 72	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 76	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 80	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 84	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 88	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 92	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 96	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 100	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 104	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 108	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 112	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 116	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 120	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 124	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 128	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 132	600 ± 0.00	300 ± 0.00	0 ± 0.00
Day 136	600 ± 0.00	300 ± 0.00	0 ± 0.00
Total	52500 ± 0.00	28000 ± 0.00	0 ± 0.00

The cost of water (Table 2) used in this study varied with source and was constant from Day 0 to Day 136. Stream water was the most expensive, followed by borehole water while rainwater was harvested free of charge. For stream water, the associated cost is for fueling vehicle to fetch the stream water while for borehole water, the associated cost is for buying fuel to pump the borehole water. At the end of the study, a total of ₦52,500 ± 0.00 was used for collecting stream water while ₦ 28,000 ± 0.00 was used in buying fuel to pump borehole water.

Economics indices C. gariepinus reared in three water sources: Normally in fish culture, economic evaluation is very crucial because it provides a reliable basis in decision making and policies formulation by the fish farmer (Ajang *et al.,* 2018). Findings of this study as presented in table 3 was based on the current cost of items as at the time of carrying out the study. The indices evaluated include; Investment cost analysis (₦), net production value, profit index (PI), and benefit cost ratio (BCR).

Cost of feed per gram and cost of fingerlings were constant standing at ₦ 0.73. ± 0.00 per gram and ₦ 750.00 for fish stocked in tanks reared with different water source. Cost of feeding was highest in fish reared in borehole water (₦ 21617.86 ± 31.77), followed by fish reared in stream water (₦ 18384.35 ± 90.99) and least in fish reared in rainwater (₦ 13635.93 ± 48.16). The cost of water used was highest in fish reared in stream water (₦52, 500 ± 0.00), followed by fish reared in borehole water (₦ 28,000 ± 0.00) while there was no cost attached to harvest of rainwater. Investment cost analysis was highest (₦ 71634.35 ± 90.99) in fish reared in stream water and least in fish reared in rainwater (₦14385.93 ± 48.16).

Net production value (NPV) was highest in fish reared in borehole water (₦ 395341.60 ± 14955.91), followed by fish reared in stream water (₦ 341905.58 ± 8916.02) and least in fish reared in rainwater (₦228659.60 ± 7109.54). Profit index was highest in fish reared in rainwater (16.77 ± 0.51), followed by fish reared in borehole water (7.97 ± 0.30). Benefit cost ratio was highest in fish reared in rainwater (15.89

± 0.49), followed by fish reared in borehole water (7.85 ± 0.30) and least in fish reared in stream water (4.77 ± 0.12). Analysis of variance for economics indices of *C. gariepinus* reared in three water sources showed that total food consumed (TFC – g), cost of feeding (₦), weight gain (WG - g), 1nvestment cost analysis (₦), Net production value (₦) and cost benefit ratio stood meaningfully diverse ($p<0.05$) with p-values of 0.0023, 0.000002, 0.0041 and 0.00001, 0.00003 and 0.00002 respectively. Mean survival and profit index were not significantly different ($p>0.05$) with p-values of 0.932 and 0.313.

Table 3: Mean economics indices *C. gariepinus* reared in three water sources

Parameters	Stream water	Borehole water	Rain water
Feed consumed (g)	25184.04 ± 124.65[a]	29613.50 ± 43.51[b]	18679.36 ± 65.97[c]
Cost of feed per gram (₦)	0.73 ± 0.00[a]	0.73 ± 0.00[b]	0.73 ± 0.00[c]
Cost of feeding (₦)	18384.35 ± 90.99[a]	21617.86 ± 31.77[b]	13635.93 ± 48.16[c]
Weight gain (g)	18016.67 ± 127.43[a]	22529.67 ± 99.57[b]	14024.33 ± 36.37[c]
No. of fish stocked	25.00 ± 0.00	25.00 ± 0.00	25.00 ± 0.00
Cost of fish stocked (₦)	750.00 ± 0.00	750.00 ± 0.00	750.00 ± 0.00
Mean survival	22.00 ± 0.58[a]	22.33 ± 0.88[a]	22.33 ± 0.67[a]
Cost of water used (₦)	52500 ± 0.00	28000 ± 0.00	0.00± 0.00
Investment cost analysis (₦)	71634.35 ± 90.99[a]	50367.86 ± 31.77[b]	14385.93 ± 48.16[c]
Net production value (₦)	341905.58 ± 8916.02[a]	395341.60 ± 14955.91[b]	228659.60 ± 7109.54[c]
Profit index (PI)	4.82 ± 0.12[a]	7.97 ± 0.30[a]	16.77 ± 0.51[a]
Benefit cost ratio	4.77 ± 0.12[a]	7.85 ± 0.30[b]	15.89 ± 0.49[c]

*means with different superscript are significantly different ($p<0.05$)

Improvement of *C. gariepinus* production is strongly influenced by a good economic analysis which involves knowledge of profitability and production constraints (Ugwumba and Chukwuji, 2010, Ajang *et al.*, 2018). In this study, two types of cost were identified, including fixed cost (cost of feed per gram and cost of fingerlings) and variable cost which include the cost of different water sources except rainwater which was free. Cost of feeding was found to increase significantly ($p < 0.05$) with growth rate and weight gain with fish reared in borehole water having the highest cost (₦ 21617.86 ± 31.77). This could be attributed to the fact that as fish grows, quantity of food consumed increases which resulted in fish reared in borehole water consuming more feed, this observation occurred in all three water sources and is in line with the findings of Ajang *et al*.,(2018). Fish reared in borehole water recorded a significant difference ($p < 0.05$) in values for net production value, investment cost analysis and gross profit for the economics indices tested when compared to fish reared in other sources. Nevertheless, all three sources of water were operationally intensive, involving greater use of inputs that included feed, labour and maintenance. Production estimates based on gross and net yield for weight and growth gain are used as basis for economic revenue estimates in fish farming operation. Umaru *et al*., (2016) and Ajang *et al*.,(2018) attributed high gross profitability to high feed quality, feed acceptability and suitability or good water quality parameters. Fish reared in borehole water performed better based on the economic evaluation which could be attributed to the water quality of borehole water most especially pH, ammonia and dissolved oxygen. This indicates that the use of borehole water for *C. gariepinus* culture is the more suitable compared to rainwater and stream water and will yield more profit which is the major aim of every commercial fish farmer. Nevertheless, the collection and use of rain water for rearing fish was observed to be cheaper and recorded a good result in terms of weight gain of the fish and was economically favorable. In aquaculture, there should be a careful consideration of inputs that will result in high investment cost analysis such as collection of stream water if high profitability is targeted. Also, for a year round culture of *C. gariepinus*, seasonal source of water such as rainwater should be avoided.

Conclusion: The use of borehole water in rearing *C. gariepinus* showed some beneficial effects compared to stream water and rain water. Growth performance and economic indices were better in fish reared in borehole water than stream water and rain water. Also, for a year round production of *C. gariepinus,* seasonal source of water such as rainwater should be avoided since it will be difficult to store adequate volume of rainwater that could feed the ponds in the dry season except the farmer wants to produce fish on seasonal basis. This study has shown that fish farmers and fish intending farmers who are challenged by borehole water supply for fish culture can alternatively harvest rainwater or collect stream water to rear fish that could be utilized at a subsistent level.

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first author or corresponding author.

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