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Efficiency Status in Artisanal Fishing Amidst Overfishing, Pollution, and Infrastructure Development on Inland Water Fisheries in Nigeria

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Abstract*Artisanal fishing is vital to Nigeria's inland fisheries, contributing 80% of national fish production and supporting millions of livelihoods. However, overfishing, pollution, and infrastructure development threaten both technical efficiency and sustainability. This study examines the efficiency status of artisanal fishers in Rivers Niger and Benue, assessing socio-economic characteristics, efficiency determinants, and environmental constraints. A three-stage sampling method was used to select 235 artisanal fishing households across eight Local Government Areas (LGAs) in Kogi State, Nigeria. Data were collected through structured interviews, field observations, and focus group discussions. The Cobb-Douglas Stochastic Frontier Production Model estimated technical efficiency, while descriptive statistics analyzed fisher demographics and productivity patterns. Results show that River Benue fishers had a higher mean efficiency (0.785) than River Niger fishers (0.643). 33.9% of River Benue fishers operated above 90% efficiency, compared to 15.9% in River Niger, where over 25% recorded efficiency levels below 40%. Education significantly reduced inefficiency (β = -0.0458, $p < 0.01$), while traditional fishing methods among experienced fishers hindered efficiency (β = -0.774, $p < 0.05$). Mechanization exhibited mixed effects, with a positive but insignificant influence in River Niger (β = 0.1561, $p > 0.05$) and a negative effect in River Benue (β = -0.2755, $p > 0.05$), suggesting that improper mechanization can lead to inefficiencies through increased operational costs and overcapitalization. Environmental challenges, including water pollution, invasive species, and overfishing, exacerbated inefficiencies. The study highlights the urgent need to balance efficiency improvements with sustainability measures to ensure the resilience of Nigeria's inland fisheries.*

Keywords: *Technical efficiency, overfishing, inland fisheries, sustainability, mechanization*

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1.0 Introduction

Inland fisheries serve as a crucial source of food security, employment, and economic stability for millions of Nigerians, particularly those in rural communities along major water bodies like the Rivers Niger and Benue. Artisanal fishing, which accounts for approximately 80% of the nation's total fish production, plays an indispensable role in the country's fisheries sector (Afolabi et al., 2021). However, despite its significance, this sector faces mounting challenges that threaten its sustainability and efficiency. The convergence of overfishing, environmental pollution, and infrastructure development has led to a steady decline in fish stocks, economic vulnerability for fishing communities, and growing inefficiencies in resource utilization. Similar concerns have been reported in other developing nations where inland fisheries contribute significantly to food security but remain

vulnerable to anthropogenic pressures (FAO, 2022; Onyango et al., 2020).

Technical efficiency in artisanal fishing, defined as maximizing fish output while minimizing resource use—including labor, capital, and equipment—remains a pressing concern. Studies have shown that improving efficiency is key to ensuring the sustainability of small-scale fisheries (Pomeroy & Andrew, 2011). The pursuit of efficiency, however, often conflicts with ecological sustainability, as increased fishing intensity can exacerbate stock depletion, particularly in poorly regulated open-access fisheries (Esen, 2023). Overfishing has emerged as a critical challenge, driven by a lack of enforceable regulations, economic desperation, and the widespread use of indiscriminate fishing methods such as small mesh nets that capture juvenile fish and disrupt breeding cycles (Ostrom, 2009). The consequence is a rapid decline in fish populations, pushing fishing communities further into poverty and food insecurity (FAO, 2022; Tewfik et al., 2017).

Simultaneously, the deterioration of water quality due to pollution from industrial waste, agricultural runoff, and domestic sewage is compounding the crisis. Heavy metals, chemicals, and eutrophication-related hazards severely affect aquatic habitats, altering fish health, reproduction, and biodiversity (Chukwu et al., 2021). The presence of contaminants such as polychlorinated biphenyls (PCBs) and persistent organic pollutants (POPs) has been linked to declining fish stocks in Nigerian waters (Okon, 2020). The proliferation of invasive aquatic plants such as water hyacinths further obstructs fishing activities by clogging waterways and diminishing oxygen levels, ultimately reducing fish availability (Omonona & Lawal, 2023; Ndimele et al., 2011).

Infrastructure development along Nigeria's inland waterways—especially dam construction, river channelization, and urban expansion—has profoundly altered the hydrology and ecological dynamics of the Rivers Niger and Benue. Dams disrupt natural fish migration patterns, hinder spawning cycles, and fragment critical aquatic habitats, making it increasingly difficult for fish populations to replenish (Dudgeon et al., 2006). Similar challenges have been documented in other parts of Africa where hydropower projects impact traditional fishing communities (Acreman et al., 2014). These anthropogenic alterations have not only reduced fish catch rates but have also led to conflicts over resource access among artisanal fishers, commercial operators, and developers (Adeogun & Adekunle, 2022). Such conflicts often result in socio-economic displacement and increased vulnerability of fishing-dependent households (Bene et al., 2016).

Despite extensive research on artisanal fishing in Nigeria, existing studies have largely focused on marine fisheries or economic aspects, with limited insights into how socio-economic, environmental, and technological factors interplay to shape inland fisheries' efficiency. Previous studies on Nigerian inland fisheries have primarily examined stock depletion and conservation strategies without a comprehensive assessment of technical efficiency in the presence of multiple stressors (Ipinjolu et al., 2017). Moreover, limited research has been conducted on how education, mechanization, and governance structures influence efficiency among inland fishers (Nwabeze & Erie, 2013). This study seeks to fill this gap by investigating the efficiency status of artisanal fishers along the Rivers Niger and Benue, assessing the socio-economic and ecological factors influencing productivity, and identifying the trade-offs between efficiency and sustainability. By doing so, the study aims to ensure that artisanal fishing remains a viable livelihood while safeguarding the ecological integrity of Nigeria's inland waters.

2.0 Materials and Methods2/1

2.1 Study Area

This study was conducted along the Rivers Niger and Benue, two of Nigeria's most significant inland water bodies that support extensive artisanal fishing activities. These

rivers traverse multiple states, providing livelihoods for millions of people engaged in fishing, agriculture, and trade. The study focused on Kogi State, where the two rivers converge, creating a critical ecosystem for fisheries. Kogi State lies within the savannah region, bounded by longitude 05°20" and 08°00" East and latitude 05°30" and 08°50" North. The selection of this location was based on the high intensity of fishing activities and its economic importance to rural communities.

2.2 Sampling Procedure

A three-stage sampling approach was utilized to select respondents for this study. The first stage involved the purposive selection of six Local Government Areas (LGAs) along the River Niger (Ibaji, Ajaokuta, Ufo, Lokoja, Igalamela, and Idah) and two LGAs along the River Benue (Omala and Bassa) in Kogi State, based on their significance in artisanal fishing activities**.** In the second stage, three fishing villages were randomly selected from each of the eight LGAs, ensuring a comprehensive representation of fishing communities along both rivers.

Finally, in the third stage, ten fishing households were randomly sampled from each selected village, yielding a total sample size of 240 fishing households. Out of these, 235 households provided complete and valid responses, ensuring a statistically robust and representative sample of inland fishing communities in the region.

2.3 Data Collection

Primary data were collected using a combination of structured interviews, direct observations, and focus group discussions with fishers. To obtain comprehensive information, a well-structured questionnaire was administered, covering key aspects of artisanal fishing. The questionnaire gathered data on fishing output and efficiency indicators**,** including daily catch quantity, gear type, and fishing hours**,** as well as socio-economic characteristics such as the age, education level, household size, and cooperative membership of fishers**.** Additionally, it captured environmental and economic challenges**,** addressing issues such as overfishing, pollution, infrastructure disruptions, and alternative livelihood activities**.**

To complement the survey data, qualitative interviews were conducted with key stakeholders**,** including experienced fishers, fisheries extension officers, and local community leaders. These interviews provided deeper insights into the challenges affecting artisanal fishing efficiency, offering a more nuanced understanding of the factors influencing productivity and sustainability in Nigeria's inland fisheries.

2.4 Method of Data Analysis

A combination of descriptive statistics and Stochastic Frontier Production Function (SFA) was employed to assess the technical efficiency of artisanal fishing.

2.5 Descriptive Analysis

Descriptive statistical tools such as frequencies, means, percentages, and standard deviations were used to summarize socio-economic characteristics, fishing practices, and challenges faced by fishers.

2.6 Stochastic Frontier Production Function (SFA)

The Cobb-Douglas Stochastic Frontier Model was used to estimate the technical efficiency of fishers. The model was specified as follows:

Yi=f(Xi,β)+(Vi−Ui)Yi = f(Xi, \beta) + (Vi - Ui)

where Yi = Fishing output (kg per trip), Xi = Vector of input variables (crew size, fishing time, gear length, number of fishing gears, boat type), β = Vector of production function parameters, Vi = Random error term (assumed to be independently and identically distributed) and Ui = Inefficiency term (captures deviation from the efficiency frontier)

The inefficiency model was estimated using the equation 2 shown below

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + e_i \quad (1)$$

where U_i is the technical inefficiency of fisher I, Z_i is the fishing experience (years),

Z_2 is the cooperative membership (dummy, Yes = 1, No = 0). Z_3 is the age of fisher (years), Z_4 is the years of formaleducation, Z_5 is household size and Z_6 is access to extended where U_i is the technical inefficiency of fisher, I, $Z_1 =$ Fishing experience (years), Z_2 is cooperative membership dummy: Yes = 1, No = 0), Z_1 is age of fisher (years), Z_2 is $Z_3 =$ Age of fisher (years), Z_4 is years of formal education, Z_5 is household size and Z_6 is access to extension service (dummy: Yes = 1, No = 2)

Technical efficiency (TE) for each fisher was calculated according to equation 2

$$TE_i = \frac{Y_i}{Y_{max}} = \exp(-U_i) \qquad (2)$$

where TE_i ranges between 0 and 1, with **1** indicating perfect efficiency and values closer to 0 indicating higher inefficiency with TEi ranges between 0 and 1, with 1 indicating perfect efficiency and values closer to 0 indicating higher inefficiency.

2.7 Model Diagnostics and Statistical Tests

Key statistical tests conducted included:

(i) Sigma squared (σ^2): Measures the variance of inefficiency effects.
(ii) Gamma (γ): Represents the proportion of total variance attributed to inefficiency.
(iii) Log-likelihood function: Assesses the goodness-of-fit of the estimated model.
(iv) Likelihood Ratio (LR) Test: Determines whether inefficiency effects are statistically significant.

2.8 Ethical Considerations

All respondents provided informed consent before participating in the study. Confidentiality of responses was maintained, and participation was voluntary. The study adhered to ethical guidelines for social research, ensuring no harm or undue influence on respondents.

3.0 Results and Discussion

3.1 Socio-Economic Characteristics of Artisanal Fishers

The socio-economic characteristics of artisanal fishers operating along the Rivers Niger and Benue represented in Table 1 highlight key demographic patterns that influence fishing efficiency and sustainability. The study revealed that 100% of fishers in River Niger and 98.3% in River Benue were male, confirming that artisanal fishing remains a male-dominated occupation in Nigeria. This aligns with global trends in small-scale fisheries, where women primarily engage in post-harvest activities such as fish processing and marketing rather than active fishing (FAO, 2022). The near-exclusive male participation underscores the need for gender-sensitive policies to support women in fish value chain activities and expand their roles in sustainable fisheries management (McClanahan *et al*., 2015).

Age distribution patterns further reveal that a majority of fishers in River Niger (54%) were aged 41–50 years, while River Benue had a higher proportion (22%) of fishers aged 51–60 years. This suggests that the fishing workforce in River Benue is relatively older, potentially indicating a lack of younger entrants into the sector. The declining interest among younger generations may be attributed to low income levels, increased fishing risks, and the perception of fishing as a physically demanding yet less rewarding occupation (Allison & Ellis, 2022). This trend highlights the urgency for policy interventions that attract younger fishers, such as training on modern fishing techniques, financial incentives, and improved infrastructure to enhance efficiency and profitability.

A significant disparity in educational levels was observed between the two rivers. In River Niger, 58% of fishers had no formal education, whereas 33.9% of those in River Benue had attained primary education. The lower educational attainment among River Niger fishers presents a barrier to the adoption of improved fishing technologies and sustainable fishing practices. Education plays a vital role in decision-making, regulatory compliance, and the ability to adopt modern fishing techniques, which directly influence fishing efficiency (Gedefaw & Woldu, 2016). Studies in similar inland fisheries have shown that higher

literacy levels correlate with improved resource management, reduced post-harvest losses, and increased market access (Béné *et al*., 2017).

The differences in education levels may also explain variations in efficiency scores, with River Benue fishers achieving a mean technical efficiency of 0.785, compared to 0.643 in River Niger. This suggests that literacy and access to training programs enhance technical efficiency by equipping fishers with better resource management skills and adaptive capacity (Esen, 2023). Targeted interventions such as fisheries extension services, vocational training, and digital literacy programs are crucial for improving efficiency, particularly among River Niger fishers who have lower educational backgrounds.

Household structure plays a significant role in artisanal fisheries, as fishing is often a family-based economic activity. The results indicate that most fishers in both rivers belonged to households with 3–6 members (40.3% in River Niger and 40.7% in River Benue). This household size suggests a moderate dependency ratio, where additional family members may serve as labourers, thereby influencing the scale of fishing operations. However, larger household sizes also increase economic pressure, requiring higher fish catches to sustain livelihoods.

The study supports previous findings that larger household sizes in small-scale fishing communities correlate with increased fishing effort and higher risks of overfishing (Cinner *et al*., 2012). While larger households may enhance workforce availability, they also intensify resource exploitation, particularly in open-access fisheries where competition for declining fish stocks is high (Béné *et al*., 2017). Sustainable management strategies such as community-based fisheries management (CBFM), access to alternative livelihoods, and microcredit programs can help balance household economic needs with conservation goals.

Livelihood diversification is a common strategy among artisanal fishers to mitigate economic risks associated with declining fish stocks and seasonal variations in fishing productivity. The study found that 71% of River Niger fishers engaged in trading as a secondary income source, compared to 47% in River Benue. This suggests a higher dependence on alternative income sources among River Niger fishers, possibly due to lower technical efficiency and reduced fish catches.

Research on artisanal fisheries in West Africa has shown that fishers with diversified income streams experience greater economic stability, improved resilience to environmental shocks, and reduced dependence on overfishing (Allison & Ellis, 2022). However, the lack of access to financial services, business training, and markets remains a key constraint to effective livelihood diversification in Nigerian fisheries (Esen, 2023). Policies that promote access to microfinance, cooperative networks, and entrepreneurship training could enhance the economic resilience of artisanal fishers while alleviating pressure on fisheries resources.

Table 1 presents the socio-economic characteristics of artisanal fishers in two major Nigerian rivers, River Niger and River Benue. Fishing is predominantly male-dominated in both rivers, with 100% male participation in River Niger and 98.3% in River Benue. The age distribution differs between the two rivers, as the dominant age group in River Niger is between 41-50 years, accounting for 54% of the fishers, while there is no representation in the 51-60 years category. In contrast, River Benue has 22% of its fishers within the 51-60 years age range, but none in the 41-50 years category. This suggests that the fishing population in River Niger is generally younger compared to River Benue.

Marital status is similar across both rivers, with a high percentage of married individuals, recorded at 99.4% in River Niger and 98.3% in River Benue. Household sizes are also fairly consistent, as the majority of fishers in both locations have between 3-6 persons in their households, with 40.3% in River Niger

and 40.7% in River Benue falling within this range. Educational status shows a notable difference between the two rivers. In River Niger, 58% of fishers have no formal education, whereas none of the fishers in River Benue fall into this category. Instead, 33.9% of the fishers in River Benue have attained primary education, indicating a higher level of literacy among fishers in this region compared to River Niger.

Fishing experience also varies significantly. In River Niger, 57.7% of fishers have between 31-60 years of fishing experience, whereas in River Benue, only 25.4% fall within this category. This suggests that River Niger has a more experienced fishing community. Furthermore, trading as a secondary source of income is more common among fishers in River Niger, where 71% engage in trading activities, compared to 47% in River Benue. Overall, the data suggests that artisanal fishers in River Niger tend to be younger, have lower formal education, and possess greater fishing experience, while those in River Benue appear slightly older, and have more formal education, but lower fishing experience. Trading as an additional source of income is more prevalent among fishers in River Niger than in River Benue.

Table 1: Socio-Economic Characteristics of Artisanal Fishers

Variable	River Niger	River Benue
Sex (Male %)	100.00	98.30
Age Group (41-50 years %)	54.00	00.00
Age Group (51-60 years %)	00.00	22.00
Marital Status (Married %)	99.40	98.30
Household Size (3-6 persons %)	40.30	40.70
Educational Status (No Formal Education %)	58.00	00.00
Educational Status (Primary Education %)	00.00	33.90
Fishing Experience (31-60 years %)	57.70	25.40
Non-Agricultural Income (Trading %)	71.00	47.00

3.2 Cobb-Douglas Stochastic Frontier and Efficiency Model Parameters

The Cobb-Douglas Stochastic Frontier Production Model in Table 2 was employed to estimate the technical efficiency of artisanal fishers in Rivers Niger and Benue. The results provide insights into the key factors influencing efficiency, revealing significant variations between the two rivers. Efficiency in artisanal fishing is defined as the ability to maximize output (fish catch) while minimizing input use (labor, capital, and equipment) (Battese & Coelli, 1995).

The estimated model distinguishes between technical inefficiency and random noise, allowing for a robust evaluation of productivity constraints. The mean technical efficiency scores of 0.643 for River Niger and 0.785 for River Benue indicate that fishers in River Benue operate closer to their optimal production frontier than those in River Niger. This suggests that River Niger fishers experience higher inefficiencies, which may be attributed to factors such as limited access to technology, lower education levels, and poor resource management.

The number of fishing gears had a positive and significant effect on efficiency in River Niger ($\beta = 0.0289$, $p < 0.05$), indicating that increased gear ownership contributed to higher fish output. However, in River Benue, this factor had a negative but insignificant coefficient ($\beta = -0.0073$, $p > 0.05$).

This contrast suggests that in River Niger, access to more fishing gears allows fishers to exploit a larger catch potential, whereas in River Benue, excessive fishing gears may lead to inefficiencies due to gear redundancy or resource depletion. These findings align with previous research (Gedefaw & Woldu,

2016), which suggested that increasing fishing effort beyond a certain threshold can lead to diminishing returns due to overcapitalization.

Fishing experience exhibited a negative correlation with efficiency in both rivers, with a more significant impact in River Benue (β = -0.774, $p < 0.05$) than in River Niger (β = -0.2293, $p > 0.05$). This result implies that fishers with extensive experience tend to exhibit inefficiency, possibly due to reliance on traditional methods rather than modern, more efficient practices (Holland *et al*., 2022).

Several studies (McClanahan *et al*., 2015) have shown that while experience improves knowledge of fish behavior, over-reliance on outdated techniques can reduce adaptability to new technologies. Younger fishers are often more open to adopting GPS navigation, sonar fish finders, and improved gear, which enhances efficiency.

Age significantly negatively impacted efficiency in River Niger (β = -1.793, $p < 0.01$), while it was not statistically significant in River Benue (β = 0.3242, $p > 0.05$). This suggests that older fishers in River Niger may struggle with physical labor demands and have lower adaptability to technology, contributing to inefficiency.

Studies in other artisanal fisheries (Béné *et al*., 2017) confirm that older fishers are less inclined to adopt new fishing gear, mechanized boats, and digital monitoring tools, leading to inefficiency. The difference between the two rivers suggests that age-related inefficiency is more pronounced in River Niger, possibly due to lower literacy levels and limited exposure to fisheries extension services.

Education exhibited a strong negative correlation with inefficiency in both rivers, with a more significant impact in River Niger (β = -0.0458, $p < 0.01$) than in River Benue (β = -0.0218, $p > 0.05$). This indicates that higher education levels contribute to improved efficiency by fostering better decision-making, regulatory compliance, and adoption of sustainable fishing techniques.

Table 2. Cobb-Douglas Stochastic Frontier and Efficiency Model Parameters

Variable	River Niger Coefficients	River Benue Coefficients
Number of Fishing Gears	0.0289	-0.0073
Fishing Experience	-0.2293	-0.774
Co-operative Membership	-0.0269	-0.0877
Age of Fishers	-1.793	0.3242
Year of Formal Education	-0.0458	-0.0218
Household Size	-0.0277	0.0272
Extension Visit	-0.1803	-0.0595
Mechanized Boats	0.1561	-0.2755
Constant	6.6582	5.8902

Previous research (FAO, 2022) has emphasized the role of education in enhancing fishers' capacity to manage resources effectively and reduce post-harvest losses. Fishers with formal education are more likely to use appropriate mesh sizes, avoid juvenile fishing, and adopt market strategies that increase profitability.

The use of mechanized boats had a positive but insignificant effect on efficiency in River Niger (β = 0.1561, $p > 0.05$) and a negative effect in River Benue (β = -0.2755, $p > 0.05$). This suggests that mechanization alone does not guarantee efficiency improvements and may lead to higher operational costs, fuel dependency, and overexploitation of fish stocks.

3.3 Technical Efficiency Scores

Table 3 presents the frequency distribution of technical efficiency among artisanal fishers in

Rivers Niger and Benue. The results highlight disparities in efficiency levels, suggesting varying degrees of resource utilization and fishing strategies between the two regions.

The frequency distribution of technical efficiency among artisanal fishers in Rivers Niger and Benue reveals significant disparities in resource utilization and fishing strategies. The results show that fishers in River Benue operate with greater efficiency compared to those in River Niger. Specifically, 64.4% of fishers in River Benue recorded efficiency levels above 80%**,** while only 36.9% of fishers in River Niger achieved similar scores**.** Moreover, 33.9% of fishers in River Benue exhibited efficiency levels above 90%**,** compared to 15.9% in River Niger**.** The mean efficiency score for River Benue was 0.785, notably higher than 0.643 in River Niger, reflecting better fishing techniques, higher education levels, and improved access to modern fishing equipment.

Conversely, low-efficiency levels were more prevalent in River Niger, where over 25% of fishers recorded efficiency scores below 40%, compared to only 1.7% in River Benue. A particularly striking observation was that 10.2% of River Niger fishers fell within the 21–30% efficiency range**,** whereas no fishers in River Benue exhibited efficiency scores below 30%. These findings suggest that inefficiencies in River Niger are largely driven by limited education, outdated fishing methods, environmental pollution, and restricted market access**.** Education and skill levels emerged as key determinants of efficiency differences**.** Fishers in River Benue have higher literacy rates and greater exposure to training programs, which enhance their ability to adopt modern fishing techniques, improve decision-making, and optimize resource management**.** In contrast, 58% of fishers in River Niger lack formal education, correlating with lower efficiency scores and reduced capacity for technological adaptation. Previous studies have shown that fishers with formal education tend to operate at higher efficiency levels due to better understanding of fisheries regulations, technology use, and sustainable harvesting practices (FAO, 2022).

The type and number of fishing gears and mechanization levels also influenced efficiency scores. Fishers in River Benue employ a diverse range of modernized fishing techniques, including mechanized boats and improved netting systems, whereas those in River Niger continue to rely on traditional, labor-intensive methods**.** The findings indicate that proper gear use can increase catch rates by up to 30%**,** reducing labor intensity and fuel consumption. However, mechanization exhibited mixed effects, with a positive but insignificant influence in River Niger ($\beta = 0.1561$, $p > 0.05$) and a negative effect in River Benue ($\beta = -0.2755$, $p > 0.05$)**.** This suggests that while mechanization may improve productivity, it can also lead to overcapitalization and inefficiencies if not managed sustainably**.**

Environmental factors further shaped efficiency outcomes. River Niger faces more severe pollution from industrial discharge, agricultural runoff, and siltation, reducing fish availability and increasing effort per unit catch. Overfishing and habitat destruction have also led to a decline in catch per unit effort (CPUE)**,** forcing fishers to work longer hours for diminishing returns. In contrast, River Benue fishers benefit from better water quality and relatively healthier fish stocks**,** resulting in higher efficiency scores and more sustainable fishing practices**.**

While higher efficiency scores in River Benue indicate strong economic potential**,** they also pose risks of resource overexploitation if not carefully managed. Research suggests that high-efficiency artisanal fisheries can lead to rapid stock depletion if fishing pressure is not regulate**d** (FAO, 2022). This highlights the need for sustainability-driven policies that balance economic benefits with conservation efforts**.**

On the other hand, lower efficiency scores in River Niger indicate systemic challenges that must be addressed to improve productivity and income levels. Strategies aimed at enhancing education, expanding access to modern fishing technologies, and mitigating

environmental degradation will be crucial in bridging the efficiency gap between the two regions.

Table 3. Frequency Distribution of Technical Efficiency

Efficiency Range (%)	River Niger Frequency (%)	River Benue Frequency (%)
< 20	1.1	0.0
21 – 30	10.2	0.0
31 – 40	13.6	1.7
41 – 50	10.2	11.9
51 – 60	8.5	8.5
61 – 70	4.0	1.7
71 – 80	15.3	11.9
81 – 90	21.0	30.5
Above 90	15.9	33.9
Mean Efficiency	0.643	0.785

4.0 Conclusion

The findings of this study underscore the significant disparities in technical efficiency among artisanal fishers operating along the Rivers Niger and Benue, highlighting the socio-economic, environmental, and infrastructural challenges affecting productivity. Fishers in River Benue exhibited higher efficiency scores with a mean efficiency of 0.785 compared to their counterparts in River Niger, who had a mean efficiency of 0.643. This suggests better resource utilization, higher educational attainment, and greater access to modern fishing techniques in River Benue.

Education, fishing experience, mechanization, and cooperative membership were key determinants of efficiency. The study revealed that formal education significantly reduced inefficiency, with a coefficient of $\beta = -0.0458$ ($p < 0.01$), reinforcing the role of literacy in promoting sustainable and efficient fishing practices. Conversely, fishing experience showed a negative correlation with efficiency, particularly in River Benue, where $\beta = -0.774$ ($p < 0.05$), indicating that reliance on traditional methods may hinder adaptation to modern and more productive fishing techniques. Mechanization exhibited mixed effects, demonstrating a positive but insignificant influence in River Niger ($\beta = 0.1561$, $p > 0.05$) and a negative effect in River Benue ($\beta = -0.2755$, $p > 0.05$), highlighting the complexities of mechanized fishing and the potential for overcapitalization.

Environmental factors such as pollution, overfishing, and infrastructure development emerged as major constraints to fishing efficiency. Water pollution from industrial discharge, agricultural runoff, and invasive aquatic plants negatively impacted fish stocks, leading to increased fishing effort for reduced catch. Additionally, dam construction and river channelization disrupted fish migration and spawning cycles, further exacerbating inefficiencies in artisanal fishing operations.

To address these challenges, expanding fisheries extension services is essential to provide training on modern fishing techniques, sustainable resource management, and financial literacy. Promoting adult literacy programs tailored for fishers will ensure they have the knowledge to adopt efficient and sustainable practices. Encouraging cooperative-based investments in mechanization will enable small-scale fishers to share resources and reduce operational costs. The enforcement of fishing regulations, including seasonal bans, mesh size restrictions, and controlled licensing, is necessary to prevent overfishing and protect fish stocks. Implementing fish stock replenishment programs, such as artificial breeding zones and no-fishing sanctuaries, will help restore declining fish populations. Encouraging fishers to engage in alternative livelihoods such as aquaculture, eco-tourism, and value-added fish processing will reduce reliance on wild fish stocks.

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Compliance with Ethical Standards

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