

Blue Economy Integration as a Management Strategy for Small-Scale Fisheries: Economic Valuation of Sustainable Coastal Aquaculture through Digital Market Platforms

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ABSTRACT

This study investigates the strategic integration of blue economy principles within Indonesian small-scale fisheries (SSF) through the deployment of digital market platforms. This study examines the integration of blue economy principles. Utilizing a quantitative secondary data analysis combined with the Total Economic Value (TEV) framework and comparative statistical testing from the Ministry of Marine Affairs and Fisheries (KKP) and the Central Bureau of Statistics (BPS) for the 2020-2025 period, the study evaluates production metrics across three primary geographic clusters. The findings demonstrate that IoT-integrated management significantly optimizes operational efficiency, evidenced by a 22.09% reduction in the Feed Conversion Ratio (FCR) and a substantial elevation of the Fishers' Exchange Rate (NTPi) via direct market linkages. Furthermore, digital traceability was found to command a 15-20% price premium in international markets, effectively internalizing sustainability into financial assets. The research concludes that while digitalization serves as a powerful catalyst for coastal prosperity and resource resilience, its success remains contingent upon closing the digital infrastructure gap. These results offer a data-driven framework for policymakers to harmonize technological acceleration with environmental stewardship in the maritime sector.

Keywords: blue economy; small-scale fisheries; digital market platforms; coastal aquaculture; economic valuation; IoT in fisheries; sustainable development; Indonesia.



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1. Introduction

Background of Blue Economy Integration in Small-Scale Fisheries

The Blue Economy paradigm has emerged as a fundamental strategic framework in the global transformation of maritime resource management, specifically designed to mitigate ecosystem degradation while addressing economic disparities in coastal zones [1]. Within the framework of Small-Scale Fisheries (SSF), the integration of blue economy principles transcends mere conservation efforts; it represents a strategic optimization of value addition through sustainable, inclusive, and economically efficient methodologies [2]. In the Indonesian context, the aquaculture sector serves as a critical pillar for national food security, yet its operational efficiency is frequently undermined by structural barriers such as restricted technological access and asymmetric market information. Statistical evidence from the Ministry of Marine Affairs and Fisheries indicates that while production volumes have shown an upward trajectory, the socio-economic welfare of small-scale farmers remains volatile due to high input costs and a lack of bargaining power against traditional intermediaries [3].

The Imperative of Economic Valuation in Sustainable Coastal Aquaculture

Economic valuations of coastal aquaculture often suffer from a reductionist focus on raw production output, neglecting the Total Economic Value (TEV) which encompasses vital ecosystem services and long-term viability. The blue economy approach emphasizes that the success of aquaculture is intrinsically linked to the health of supporting ecosystems, such as mangrove forests and seawater quality. Failing to internalize environmental costs within aquaculture business models leads to the depletion of natural capital, which eventually erodes economic productivity. Consequently, there is an urgent need for management models capable of quantifying the economic dividends of eco-friendly farming practices to serve as financial incentives for small-scale operators [4].

Digital Market Platforms as Strategic Catalysts

The digital transformation of the fisheries sector through specialized market platforms offers a disruptive solution to the supply chain inefficiencies that have historically burdened the SSF sector. Digital ecosystems created by platforms such as *e-Fishery*, *Aruna*, and *FishLog* facilitate price transparency, optimize feed efficiency through Internet of Things (IoT) applications, and establish direct linkages to end-consumers. The implementation of these technologies significantly bolsters the Fishers' Exchange Rate (NTPi) by eliminating redundant distributive layers. Data from the Indonesian Central Bureau of Statistics confirms



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that digitalization within the agrifood and fisheries sectors has played a decisive role in stabilizing coastal household incomes during periods of global economic turbulence [5].

Management and Policy Challenges in Coastal Regions

Despite the profound potential of digitalization, the management of small-scale fisheries strategies faces significant headwinds, primarily characterized by the digital infrastructure gap and limited technological literacy in marginalized coastal areas. Management policies are often fragmented, failing to create a synergy between environmental protection and the acceleration of the digital economy. As a result, the adoption of digital platforms has only reached the upper strata of the farming population. To achieve a comprehensive integration of the blue economy, management strategies must encompass technical education, robust data infrastructure, and regulatory frameworks that safeguard the economic rights of small-scale farmers within the digital landscape [6].

Research Objectives and Academic Originality

While prior studies have explored blue economy frameworks and fisheries digitalization independently, empirical integration of digital platforms within the TEV-based valuation of small-scale fisheries remains underexplored. The scholarly novelty of this study lies in its utilization of raw secondary data from official institutions to validate the economic impact of transitioning toward sustainable practices supported by high-tech interventions. This research is intended to offer strategic evidence-based recommendations for coastal resource managers to formulate policies that are data-driven and oriented toward the prosperity of small-scale fishers.

2. Materials and Method

Research Framework and Data Acquisition

This study adopts a descriptive quantitative methodology, utilizing the Secondary Data Analysis (SDA) approach. The primary analytical objective is to perform an economic valuation of digital platform integration within small-scale fisheries (SSF). Data were collected and processed using structured secondary data extraction techniques from official ministerial and institutional databases covering the 2020-2025 period. The primary datasets were extracted from the Satu Data portal of the Ministry of Marine Affairs and Fisheries (KKP) for production metrics, the Indonesian Central Bureau of Statistics (BPS) for the Fishers' Exchange Rate (NTPi) indices, and Agrotechnology Impact Reports (e-Fishery & Aruna) [7, 8] to capture digital operational efficiency variables [3].



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Population and Data Sampling Strategy

The research population encompasses all small-scale fish farmers in Indonesia registered under the KUSUKA (Marine and Fisheries Business Actor Card) system, totaling approximately 1.2 million individuals. Given the vast geographical dispersion, this study utilizes aggregate data sampling representing three pivotal blue economy clusters in Indonesia:

- Java Cluster (West Java & East Java): Focused on freshwater aquaculture (Tilapia and Catfish) with the highest digital platform penetration at 65%.
 - Sulawesi Cluster (South Sulawesi): Centered on Seaweed and Vaname Shrimp cultivation as primary blue economy export commodities.
 - Nusa Tenggara Cluster (West Nusa Tenggara): Concentrated on sustainable marine aquaculture development.
- The secondary data analyzed includes 45,000 anonymized daily transaction points provided by digital platform stakeholders to observe price fluctuations and feed efficiency trends.

Economic Valuation Procedures

The economic assessment was conducted using the Total Economic Value (TEV) framework. The mathematical modeling utilized to calculate the economic benefits derived from digital platform integration is defined as follows:

$$TEV = \sum_{i=1}^n (P_{di} \cdot Q_i - C_{di}) + ESV$$

Where:

- P_{di} : Selling price of commodities via digital platforms.
- Q_i : Total volume of fish/shrimp production.
- C_{di} : Operational costs post-digital efficiency (feed, energy, logistics).
- ESV : Ecosystem Services Value (Value of preserved coastal ecosystem services).

Digital efficiency analysis was quantified by comparing the Feed Conversion Ratio (FCR) before and after the implementation of IoT-integrated devices linked to digital market ecosystems [8].



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Data Access Protocol and Ethical Considerations

All data utilized in this investigation were sourced from legitimate open-access databases and public institutional reports. No direct interventions involving human or animal subjects were conducted; thus, clinical ethical approval was not required. Transactional data from agrotechnology startups were utilized based on third-party audited public impact reports to ensure the privacy and confidentiality of small-scale farmers.

3. Result

Evaluating Production Trajectories and Feed Efficiency via IoT Integration

The empirical analysis indicates a major transition in operational efficiency following the adoption of digital management ecosystems. Drawing from secondary datasets provided by the Satu Data KKP portal and e-Fishery impact assessments, a quantifiable decrease in the Feed Conversion Ratio (FCR) was observed among small-holder tilapia and shrimp producers. Prior to incorporating automated IoT-based feeding systems, the mean FCR was recorded at 1.72; however, post-integration metrics reveal a contraction to 1.34. This 22.09% optimization in feed utilization correlates directly with reduced overheads, given that feed accounts for approximately 60-70% of total expenditure in coastal aquaculture.

Table 1. Comparative Performance: Conventional vs. Digitally Integrated Aquaculture (2021-2024)

Performance Indicator	Conventional Baseline (Mean)	Digitally Augmented (Mean)	Improvement (%)
Feed Conversion Ratio (FCR)	1.72	1.34	22.09
Mean Harvest Cycle (Days)	120.00	105.00	12.50
Survival Rate (SR)	72.50	88.40	21.93
Water Quality Index Stability (%)	64.00	91.00	42.18
Statistical Significance	$t(118) = 4.56$	$p < 0.001$	$d = 0.82$

Source: Synthesized from KKP Production Statistics (2023) and e-Fishery Impact Reports (2022-2023).



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Economic Valuation and Dynamics of the Fishers' Exchange Rate (NTPi)

The deployment of digital marketplace platforms has fundamentally restructured the pricing architecture for small-scale fisheries (SSF). Longitudinal data from the Indonesian Central Bureau of Statistics (BPS) demonstrates that the Fishers' Exchange Rate (NTPi) for stakeholders within digital ecosystems consistently outperforms the national baseline. By circumventing conventional middlemen, producers leverage "fair pricing" models that align with real-time market oscillations. Independent t-test results indicate a significant divergence in monthly earnings between digitally integrated and traditional producers, $t(500) = 6.12, p = 0.001, \eta^2 = 0.15$ [5].

Table 2. Breakdown of Economic Valuation for Small-Scale Coastal Aquaculture

Valuation Component	Traditional Baseline (IDR/Kg)	Digital Ecosystem (IDR/Kg)	Net Surplus (IDR/Kg)
Direct Commodity Sales	22,500	28,000	5,500
Intermediary/Logistics Deductions	(4,500)	(1,200)	3,300
Informational Equity Value	0	1,500	1,500
Ecosystem Service Premium	500	2,000	1,500
Aggregate Economic Value	18,500	30,300	11,800

Source: Reconstructed from Aruna Impact Studies (2023) and BPS NTPi Monthly Bulletins (2024).

Spatial Heterogeneity in Blue Economy Adoption and Yield

Geospatial assessment across three primary clusters Java, Sulawesi, and Nusa Tenggara confirms that provinces with superior digital infrastructure and literacy exhibit higher Blue Economy performance indices. The Java cluster, characterized by high-intensity tilapia farming, demonstrates the most accelerated adoption of marketplace technology. Conversely, the Sulawesi cluster shows a marked increase in the economic valuation of seaweed through digital traceability, which commands superior export premiums [1].



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Table 3. Regional Yield Analysis and Digital Adoption Prevalence (2023)

Geographic Cluster	Digital Adoption (%)	Production Volume (Tons)	Valuation (Billion IDR)
Java Cluster	65.40	450,200	1,200.50
Sulawesi Cluster	38.20	310,500	890.30
Nusa Tenggara	22.10	120,800	340.20
Other Regions	15.50	210,400	410.60
National Aggregate	35.30	1,091,900	2,841.60

Source: Analysis of Satu Data KKP (2024) and Bappenas Blue Economy Framework (2021).

Influence of Digital Traceability on Global Market Valuation

A pivotal finding of this study is the positive correlation between blockchain-enabled traceability and international market access. Coastal aquaculture products registered on digital platforms such as Aruna or FishLog secure premium pricing globally. Data suggests that "Blue Certified" traceable commodities carry a 15-20% higher valuation relative to non-traceable counterparts. This trend is particularly salient in the Vaname shrimp and seaweed sub-sectors, where global buyers necessitate rigorous sustainability documentation.

4. Discussion

Reconciling Digital Efficiency with Blue Economy Paradigms

The evidence presented in this investigation validates that the assimilation of digital market ecosystems is far more than a mere technological upgrade; it signifies a fundamental shift in the strategic governance of small-scale fisheries (SSF). The 22.09% reduction in the Feed Conversion Ratio (FCR) achieved through IoT interventions demonstrates that economic optimization can exist in a symbiotic relationship with environmental conservation. From a blue economy perspective, minimizing surplus feed not only curtails overhead costs but also mitigates the risk of coastal eutrophication, a primary threat to marine biodiversity. This reinforces the premise that precision aquaculture can decouple economic growth from negative externalities while simultaneously bolstering the profitability of small-scale producers [9].

Supply Chain Disruption and the Pursuit of Social Equity

The substantial rise in the Fishers' Exchange Rate (NTPi) among digital platform users confirms that informational asymmetry has been a structural bottleneck for coastal welfare. By circumventing traditional intermediary layers, digital platforms redistribute economic



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surplus directly back to the primary producers. Theoretically, this alignment supports the "social equity" pillar of the blue economy, which mandates that local communities should be the principal beneficiaries of marine resources. However, the data also highlights a looming risk of "digital exclusion" for fishers in marginalized zones, such as the Nusa Tenggara cluster, where adoption remains low at 22.10%. This disparity suggests that management strategies must prioritize the development of connectivity infrastructure as a prerequisite for achieving inclusive economic justice [10].

Digital Traceability as an Instrument of Global Market Valuation

The discovery of a 15–20% price premium for commodities with digital footprints marks a turning point for Indonesia's export competitiveness. Long , particularly within the European Union and North America, are increasingly demanding radical transparency regarding product provenance and ecological impact. Blockchain-enabled traceability, integrated into platforms like Aruna, provides global buyers with high-fidelity assurance that products are not linked to mangrove deforestation or labor exploitation. Consequently, digitalization acts as an economic valuation instrument that converts "sustainable practices" into tangible financial assets for small-scale operators [12].

Policy Implications and Future Research Trajectories

The future of fisheries management must transition from volume-centric models to value-driven, data-oriented frameworks. It is imperative for the government to integrate data from private digital platforms into the national "Satu Data KKP" system to foster policies that are more sensitive to real-time market shifts. A limitation of this study is its reliance on aggregated secondary data, which may overlook the specific socio-cultural nuances of individual coastal villages. Future research should investigate the application of Artificial Intelligence (AI) in forecasting climate change risks for coastal aquaculture to strengthen the resilience aspect of the blue economy framework [13].

5. Conclusions

Research Conclusion

The integration of blue economy principles as a management strategy for small-scale fisheries (SSF) through digital market platforms has been demonstrated to significantly enhance both economic valuation and operational longevity. This research concludes that transitioning from traditional methodologies to digital ecosystems optimizes feed efficiency by 22.09% and bolsters farmer income through more equitable and transparent pricing



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mechanisms. Theoretically, this study expands the blue economy framework by proving that digital technology serves as a vital instrument for internalizing sustainability values into concrete financial gains. Digital traceability has evolved from a secondary feature into a strategic economic asset that secures access to global premium markets and strengthens the bargaining power of small-scale producers within international value chains [11].

Nonetheless, this study acknowledges certain constraints regarding the generalization of these results. The efficacy of such strategies is heavily contingent upon the maturity of regional digital infrastructure and the level of technological literacy within coastal communities. The digital divide observed in specific geographic clusters suggests that without inclusive policy interventions, digitalization risks fostering new forms of inequality within SSF communities. Despite these challenges, this research has substantially advanced scientific understanding by quantifying the correlation between IoT-based feed efficiency, digital price transparency, and the elevation of the Fishers' Exchange Rate (NTPi) within the blue economy paradigm.

Suggestions and Recommendations

Based on the implications of this research, several strategic recommendations are proposed:

Strengthening Coastal Digital Infrastructure: The government must prioritize the deployment of telecommunication towers and internet networks in remote coastal villages to ensure blue economy inclusivity for all strata of small-scale fish farmers.

Sectoral Data Integration: Formal collaboration between private digital platform providers and the national "Satu Data KKP" system is recommended to establish a precise, real-time fisheries management database that supports evidence-based policymaking.

Incentives for Sustainable Practices: Regulators should develop incentive schemes for producers who adopt traceability technologies, recognizing their contribution to the preservation of coastal ecosystems .

Directions for Future Research: Future investigations should explore the integration of Artificial Intelligence (AI) to mitigate climate disaster risks in the aquaculture sector and conduct longitudinal analyses on the long-term impacts of digitalization on the socio-economic structures of coastal societies.



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