INTISARI

Integrasi Inovasi Digital Berbasis *Hardware* dan *Software* dalam *Smart Aquaculture*: Analisis Gap dan Strategi Penguatan Budidaya Udang Vaname (*Penaeus vannamei,* Boone 1931) di JALA

Transformasi digital dalam sektor akuakultur berkembang pesat seiring meningkatnya kebutuhan pada sistem produksi yang efisien dan berkelanjutan. Sebagian besar kajian masih memisahkan antara inovasi teknologi dan evaluasi keberlanjutan, serta keterkaitan keduanya belum dipahami secara komprehensif. Penelitian ini bertujuan untuk menganalisis integrasi inovasi digital berbasis *hardware* dan *software* dalam sistem *smart aquaculture* JALA; mengevaluasi dampaknya terhadap dimensi keberlanjutan lingkungan, ekonomi, dan sosial; mengidentifikasi kesenjangan (gap) implementasi; serta mengembangkan kerangka strategis penguatan integrasi inovasi keberlanjutan dalam ekosistem budidaya udang vaname (*Penaeus vannamei*). Penelitian ini menggunakan desain studi kasus dengan pendekatan campuran (*mixed methods*). Data kuantitatif dianalisis dari 460 siklus produksi dan 1.721 tambak mitra JALA periode 2023–2024, mencakup indikator *Feed Conversion Ratio* (FCR), produktivitas, *survival rate*, dan profitabilitas. Data kualitatif dan kuantitatif diperoleh melalui wawancara mendalam, observasi lapangan, dan analisis dokumen, serta diperkuat dengan data *Customer Satisfaction Score* (CSAT) 2024. Analisis kesenjangan dilakukan menggunakan pendekatan *fishbone analysis* untuk mengidentifikasi faktor sosio-teknis yang memengaruhi kinerja sistem. Hasil penelitian menunjukkan bahwa sistem *smart aquaculture* JALA membentuk sistem sosio-teknis berbasis data, dengan perangkat *hardware* berfungsi sebagai sumber data lingkungan dan *software* berperan sebagai *decision-support system*. Secara kuantitatif, efisiensi pakan (FCR) berpengaruh negatif dan signifikan terhadap profitabilitas, sedangkan produktivitas udang berpengaruh positif dan signifikan terhadap produktivitas. Sebaliknya, sintasan atau *survival rate* udang tidak menunjukkan pengaruh signifikan secara langsung. Dari dimensi sosial, tingkat penerimaan pengguna terhadap software relatif tinggi, sedangkan *hardware* masih menghadapi tantangan pada aspek akurasi dan sinkronisasi data. Analisis gap menunjukkan bahwa hambatan utama bersifat sistemik, mencakup kualitas data, perilaku pengguna, proses operasional, dan tata kelola ekosistem. Penelitian ini menghasilkan kerangka strategis untuk mendukung *scaling* integrasi inovasi digital dan keberlanjutan, dengan menempatkan keberlanjutan sebagai prinsip desain sistem (*sustainability-by-design*) dalam *smart aquaculture*.

Kata kunci: *smart aquaculture*, inovasi digital, keberlanjutan, budidaya udang, sistem sosio-teknis

ABSTRACT

Integrating Software and Hardware Based Digital Innovations in Smart Aquaculture: Gap Analysis and Strategic Framework for Whiteleg Shrimp (*Penaeus Vannamei,* Boone 1931) Farming at JALA

Digital transformation in aquaculture has accelerated in response to growing demands for efficient and sustainable production systems. However, existing studies often address technological innovation and sustainability as separate domains, resulting in limited understanding of their systemic integration. This study aims to analyze the integration of software- and hardware-based digital innovations within JALA s smart aquaculture system, evaluate their impacts on environmental, economic, and social sustainability, identify implementation gaps, and develop a strategic framework to strengthen innovation–sustainability integration in whiteleg shrimp (*Penaeus vannamei*) farming. This research adopts a case study design using a mixed-methods approach. Quantitative analysis is based on 460 production cycles from 1,721 shrimp ponds operated by JALA partners during 2023–2024, covering key performance indicators such as Feed Conversion Ratio (FCR), productivity, survival rate, and profitability. Qualitative and quantitative data were collected through in-depth interviews, field observations, and document analysis, complemented by Customer Satisfaction Score (CSAT) 2024 data. A fishbone analysis was employed to identify socio-technical gaps affecting system performance and sustainability outcomes. The results demonstrate that JALA s smart aquaculture system operates as a data-driven socio-technical system, where hardware devices provide environmental data and the digital platform functions as a decision-support system. Quantitative findings reveal that FCR has a significant negative effect on profitability, while productivity has a significant positive effect. In contrast, survival rate does not show a statistically significant direct impact. From a social perspective, user acceptance of the software platform is relatively high, whereas hardware faces challenges related to sensor accuracy and data synchronization. Gap analysis indicates that the primary constraints are systemic rather than purely technological, involving data quality, user behavior, operational processes, and ecosystem governance. This study proposes a strategic framework for scaling innovation–sustainability integration, emphasizing sustainability-by-design as a core principle in smart aquaculture development. The findings contribute to both theoretical and practical understanding of how digital innovation can be institutionalized to support sustainable aquaculture systems.

Keywords: smart aquaculture, digital innovation, sustainability, shrimp farming, socio-technical systems