Advances in Consumer Research
https://acr-journal.com/

Volume-2 | Issue-4 | Sep 2025

Original Researcher Article

Digital Transformation in the Agriculture and Fisheries Sector for Sustainable Economic Development

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Received:01/08/2025
Revised: 15/08/2025
Accepted:04/09/2025
Published:21/09/2025

ABSTRACT
Digital transformation has become one of the main drivers of change in the agricultural and fisheries sectors, particularly in supporting sustainable economic development in regions highly dependent on primary sectors such as Polewali Mandar Regency, West Sulawesi. This study aims to analyze the impact of digital technology adoption on productivity, efficiency, community income, and its contribution to local economic sustainability. The research employed a mixed-method approach, combining qualitative and quantitative techniques, involving 100 respondents (50 farmers and 50 fishers) through offline questionnaires, in-depth interviews, and field observations. Secondary data were obtained from the Central Bureau of Statistics (BPS), the Ministry of Agriculture, the Ministry of Marine Affairs and Fisheries, and relevant local government reports. The findings indicate that the adoption of digital tools—such as marketplace applications, weather prediction systems, e-fishery platforms, and digital cold chains—has increased rice productivity by 14–16% (with a baseline of 4.98 tons/ha) and reduced post-harvest fishery losses from 27% to 18%. The income of farmers and fishers adopting digital technologies rose by an average of IDR 2–3 million per month compared to their conventional counterparts. Nevertheless, challenges remain, including limited internet infrastructure, low digital literacy particularly among older respondents, and difficulties in distributing offline questionnaires in rural and coastal areas. Overall, this study affirms that digital transformation holds significant potential to strengthen the economic resilience of regions reliant on primary sectors, enhance community welfare, and support sustainable development. The success of implementation, however, depends heavily on supportive policies, improved digital literacy, and strong collaboration among government, academia, and the private sector to accelerate technology adoption.

Keywords: Digital Transformation; Agriculture and Fisheries; IoT Technology; Big Data; Sustainable Economic Development.

INTRODUCTION

In the era of globalization characterized by rapid change and increasing competition, digital transformation has become one of the main drivers of development across various sectors, including agriculture and fisheries. These two sectors, which have long served as the backbone of Indonesia's economy, are now facing global challenges such as climate change, population growth, limited land availability, and excessive exploitation of natural resources. Such conditions demand a new approach that is more adaptive, efficient, and sustainable. Digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and Geographic Information Systems (GIS) provide significant opportunities to address these challenges through real-time monitoring, more accurate data processing, and evidence-based decision-making [1–3].

In Indonesia, the agriculture and fisheries sectors play a strategic role in ensuring food security as well as driving the national economy. However, global issues such as extreme weather, environmental degradation, and supply chain imbalances often hinder productivity. For example, climate change has disrupted the planting patterns of rice and maize, while overfishing practices threaten the sustainability of marine ecosystems. Digital transformation is believed to offer solutions by improving production management, distribution systems, and risk management through data-driven innovation [4].

Beyond technical benefits, digitalization also carries social and economic implications. Data-driven monitoring systems enable farmers and fishers to respond more quickly to environmental changes, while connectivity to digital platforms improves price

transparency, broadens market access, and encourages more inclusive business models [5]. In practice, digital marketing has been proven to increase sales of agricultural and fishery products, as highlighted by local studies emphasizing the importance of digital literacy among MSMEs [6]. Nonetheless, significant barriers remain, including limited internet infrastructure in rural areas, low digital literacy among older farmers and fishers, and resistance to changes in traditional work patterns [7,8].

The key question that arises is how digital technologies can be optimally integrated to address these issues. While the use of IoT, AI, and big data promises productivity gains through continuous monitoring and data-driven decision-making, effectiveness at the local level is often constrained by technological gaps. Traditional production processes are less responsive to rapid changes in the field, while low digital literacy limits the capacity of farmers and fishers to fully harness digital opportunities. This raises doubts about whether digitalization can be evenly applied across regions with diverse socio-economic conditions.

Furthermore, debates have emerged regarding the impact of digitalization on supply chain sustainability. Although in theory digitalization can enhance distribution transparency, in practice it does not necessarily guarantee environmental sustainability. The pressure to achieve sustainable economic development requires that digital transformation not only focus on economic efficiency but also consider ecosystem preservation. Moreover, integration into digital ecosystems does not automatically ensure success. Many MSMEs, despite being connected, still struggle to compete in digital markets due to limited strategies and technical capacity. Thus, structured training, mentorship, and the development of adaptive business strategies aligned with local needs are crucial [8].

Within the context of this study, novelty lies in an interdisciplinary approach that not only examines the technical aspects of digital technology adoption but also evaluates its impacts on social, economic, and environmental dimensions. Previous research, such as Wolfert et al. (2017) and Klerkx et al. (2019), has highlighted the technical benefits of agricultural digitalization through improved productivity and efficiency [9,10]. However, locally contextualized studies, such as in Polewali Mandar, remain limited. By combining qualitative and quantitative methods through surveys, interviews, and pilot experiments, this study seeks to produce a comprehensive analytical model and strategic recommendations. Its main objective is to answer fundamental questions regarding the effectiveness of digitalization in improving productivity, strengthening supply chain transparency, overcoming implementation barriers, and supporting environmental sustainability in the agriculture and fisheries sectors [11].

LITERATURE REVIEW

The literature review shows that the digitalization of agriculture and fisheries has developed rapidly over the past two decades alongside the emergence of technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and Geographic Information Systems (GIS). Numerous studies confirm that the application of these technologies can enhance productivity, distribution efficiency, and environmental sustainability. Wolfert et al. (2017) [1] emphasized that big data in smart farming forms the foundation for improving the accuracy of weather prediction, agricultural input management, and strategic decision-making. Their study highlights that digital technologies are not merely supporting tools, but also critical instruments in transforming global food production systems.

Klerkx, Jakku, and Labarthe (2019) [2] reviewed social science literature on agricultural digitalization, framing it as part of the Agriculture 4.0 revolution. They stressed the importance of social, economic, and cultural understanding in integrating technologies. The study pointed out that the greatest challenge is not the availability of technology, but rather the highly varied adoption levels among farmers and fishers, particularly in developing countries. Meanwhile, Kamilaris et al. (2017) [3] noted that big data has enhanced agricultural efficiency through the analysis of water, fertilizer, and pesticide consumption patterns, but also highlighted the need for adequate data infrastructure and human resource capacity.

In the fisheries sector, Torres and Alvarez (2018) [4] explained that digital transformation has influenced stock management, fishing practices, and cold chain management. Sensor technologies, digital mapping, and catch-monitoring applications have been shown to reduce post-harvest losses by up to 30%. This aligns with the FAO (2021) [12] report, which stressed that digitalization in fisheries plays an essential role in preventing overfishing and enhancing product traceability from the sea to the consumer.

On the economic side, Kraus et al. (2020) [5] revealed that digital transformation opens new opportunities for MSMEs in agribusiness, but also presents challenges such as capital requirements, digital skills, and integration into global supply chains. This is consistent with Smith et al. (2018) [7], who underscored the importance of digital literacy training programs to strengthen the readiness of small-scale enterprises in facing competition in the digital era.

Local literature also reflects similar dynamics. Marufi, Saleh, and Zainuddin (2025) [6] found that digital marketing significantly contributed to increased sales at Wonomulyo Pharmacy in Polewali Mandar. This study demonstrates that digital strategies can be applied not only in the health sector but also in agriculture and fisheries, provided that the right marketing strategies are implemented. Saleh (2023) [8] further highlighted that MSMEs in Polewali Mandar face serious challenges in

digital literacy, yet they have demonstrated resilience by developing community-based local adaptations.

From a policy perspective, reports from FAO (2018) [9], the World Bank (2016) [10], and the OECD (2019) [11] highlight that agricultural and fisheries digitalization is a key strategy to achieve global food security, social inclusion, and sustainable economic development. However, these reports also stress the persistence of digital divides between regions, particularly in developing countries, which may exacerbate socio-economic inequalities if not addressed through proper policy interventions.

Accordingly, this study seeks to fill this gap by adopting an interdisciplinary approach. Its primary focus is to evaluate the effectiveness of digital transformation in enhancing agricultural and fisheries productivity, reducing risks, strengthening social inclusion, and supporting sustainable economic development at the local level.

RESEARCH METHODOLOGY

This study was conducted in Polewali Mandar Regency, West Sulawesi, which is recognized as one of the regions whose economy is primarily based on agriculture and fisheries. The location was purposively selected by considering the varying levels of digital technology adoption, the diversity of key commodities, and the availability of data access. With these conditions, Polewali Mandar is considered representative in illustrating how digital transformation affects sustainable economic development in the primary sector.

The research employed a mixed-method approach, integrating both qualitative and quantitative methods. This approach was chosen to obtain a comprehensive understanding, not only regarding the influence of digital technology on productivity and income but also concerning social dynamics, challenges, and adaptive strategies adopted by farmers and fishers at the local level.

The research stages began with problem formulation, namely identifying fundamental issues related to the low level of digitalization in agriculture and fisheries, as well as the potential benefits offered by technology adoption. This stage aimed to clarify the research focus and formulate relevant research questions.

Subsequently, the identification of research variables was carried out. The main variables observed included the level of digital technology adoption, farm or fishery productivity, income levels, as well as supporting and inhibiting factors of digitalization. This identification also established the scope of the research, including the specific sectors and digital technologies studied, such as agricultural marketing applications, weather sensors, e-fishery applications, GPS systems, and cold chain management.

The next stage was the selection of research locations and samples. The research sites were determined in villages across several districts in Polewali Mandar that had initiated or experienced the use of digital technologies in agriculture and fisheries. This selection was based on the level of digital development already adopted by the community and the availability of practitioners willing to participate. A purposive sampling technique was used, with 50 respondents consisting of 25 farmers and 25 fishers. Respondents were chosen based on their direct involvement in digital technology use, ensuring the data collected was relevant and representative.

Data collection employed three main techniques. First, quantitative surveys using questionnaires measured digital adoption levels, productivity, income, and respondents' perceptions of supporting and inhibiting factors. The instruments were tested for validity and reliability using Cronbach's alpha. Second, in-depth interviews were conducted to gather qualitative insights regarding experiences, motivations, and adaptation strategies toward digitalization. Third, field observations were carried out to directly verify the application of digital technologies in agricultural and fisheries practices, such as the use of marketplace applications, weather sensors, and digital logistics systems.

After the data was collected, the study identified priority sectors. At this stage, the research focused on the extent to which digitalization strengthened Polewali Mandar's key commodities, such as rice, corn, cocoa, coconut, and capture and aquaculture fisheries. This exploration also linked digitalization to digital business analysis, regional economics, marketing, and the use of data sciences and ICT as instruments for strengthening competitiveness.

Data modeling was then conducted using two approaches. Qualitative analysis employed thematic analysis to extract major themes from interviews and observations. Quantitative analysis used descriptive statistics to describe respondent profiles and adoption levels, as well as linear regression to measure the influence of digital technology adoption on productivity and income. Classical assumption tests such as normality, multicollinearity, and heteroscedasticity were also conducted to ensure the validity of the analytical models.

Based on the analysis, the next stage was the formulation of digitalization strategies for the agriculture and fisheries sectors. This stage identified strategic priorities, mapped inhibiting factors, and evaluated variables most influential to successful digitalization. It also included gap analysis and policy recommendations for local governments, business actors, and educational institutions.

The final stage was drawing conclusions, where all data and findings were synthesized to assess the economic,

social, and environmental impacts of digitalization. These conclusions also provided practical recommendations for developing a digital ecosystem in agriculture and fisheries that supports sustainable economic development.

Through systematic stages ranging from problem identification, site selection, data collection, analysis, to strategy formulation and conclusion this study is expected to provide a comprehensive picture of the role of digital transformation in improving productivity, income, and sustainable economic development in the agriculture and fisheries sectors of Polewali Mandar.

RESEARCH RESULTS

The analysis of research findings on digital transformation in the agricultural and fisheries sectors of Polewali Mandar Regency demonstrates that digitalization has had a tangible impact on improving productivity, efficiency, and community income, although adoption levels remain uneven across different groups. The study involved 100 respondents, consisting of 50 farmers and 50 fishers, selected using purposive sampling. Data were collected through a mixed-method approach, combining quantitative survey results with qualitative insights from interviews and field observations.

From the perspective of age, respondents in the productive age group (31–40 years) were found to be more adaptive to digital technology, actively utilizing mobile-based applications in agricultural and fishery activities compared to respondents aged over 50, who adapted more slowly. This highlights the digital literacy gap that must be addressed, especially among older generations still bound to traditional work patterns.

In the agricultural sector, farmers using weather prediction applications, soil sensors, and digital marketplaces reported an average increase in rice productivity of 14–16 percent compared to traditional farmers. Weather apps supported more accurate planting schedules, while online marketplaces shortened distribution chains and raised selling prices at the farmer level. Interviews revealed that young farmers felt more confident in managing their land with digital tools, as they gained access to real-time information and broader markets. However, persistent challenges include limited internet access in rural areas and high initial costs of acquiring digital devices.

In the fisheries sector, digital transformation also generated positive outcomes. Fishers using GPS and weather monitoring systems reduced fuel consumption by 10–12 percent due to more efficient navigation to fishing grounds. The adoption of digital cold chain systems reduced post-harvest losses from 27 percent to 18 percent. Consequently, digital fishers' incomes increased by an average of IDR 1.5–2 million per month compared to those relying on traditional methods. Interviews indicated that cold storage enabled fishers to maintain product quality, resulting in more stable market prices. However, some senior fishers remained resistant to digital adoption due to limited technological knowledge and concerns over additional costs.

Education levels were also found to influence adoption rates. Respondents with secondary education (junior to senior high school) were able to use simple digital tools such as weather applications and marketplaces, while those with higher education were quicker to grasp the benefits of digitalization and generally fell into the high-adoption category. This underscores digital literacy as a key factor for successful digital transformation in Polewali Mandar.

Socio-economically, digitalization has shifted work patterns and market interactions. Younger generations are more confident in marketing products online, while older generations still rely on traditional distribution channels. Digital platforms also fostered price transparency, strengthening the bargaining position of farmers and fishers compared to before. Nevertheless, generational gaps must be carefully addressed to ensure equitable benefits.

From a sustainability perspective, digital technologies brought environmental advantages. Data-based fertilization recommendations reduced excessive chemical fertilizer use in agriculture, while catch-monitoring applications helped prevent overfishing in fisheries. Thus, digitalization not only enhanced productivity and economic welfare but also supported wiser management of natural resources.

Overall, the findings indicate that digital transformation in Polewali Mandar's agricultural and fisheries sectors has begun and is yielding positive impacts, though not yet fully optimized. Barriers such as limited infrastructure, low digital literacy, and high initial costs remain major challenges. Therefore, strategies to strengthen digital literacy, expand infrastructure support, and foster collaboration among government, private sector, and educational institutions are urgently needed to ensure digital transformation effectively drives sustainable economic development in Polewali Mandar.

DISCUSSION

A. Digitalization of the Agriculture and Fisheries Sector

The findings of this study indicate that digital transformation has begun to play an important role in improving productivity, efficiency, and community welfare in Polewali Mandar Regency. Overall, quantitative data obtained from 100 respondents—consisting of 50 farmers and 50 fishers—demonstrate an increase in agricultural and fishery productivity following the adoption of digital technologies. This increase is not independent, but is influenced by factors such as age, education level, infrastructure access, and the digital literacy capacity of the community.

In the agricultural sector, the use of weather prediction applications, soil sensors, and digital marketing

platforms significantly boosted rice yields by an average of 14–16 percent compared to farmers using conventional methods. This suggests that digital technology provides tangible efficiency gains in both production and distribution stages. More accurate weather information enables farmers to plan planting schedules more effectively, thereby reducing the risk of crop failure due to extreme weather. Meanwhile, online marketplaces offer broader access to buyers, shorten distribution chains, and improve producer-level selling prices.

The fisheries sector also showed significant results. The use of GPS and weather monitoring systems helped fishers locate fishing grounds more quickly and efficiently, reducing fuel consumption by 10–12 percent. This indicates that digitalization improves not only catch yields but also operational cost savings, which directly contributes to higher income. Additionally, the adoption of digital cold storage reduced post-harvest losses from 27 percent to 18 percent. This demonstrates that technology-based post-harvest management not only preserves fish quality but also enhances the competitiveness of Polewali Mandar's fishery products in wider markets.

From a social perspective, the findings reveal disparities in digital adoption. Younger generations (aged 20–40) adapt more quickly to digital applications, while older generations adapt more slowly due to limited digital literacy and reliance on traditional practices. This illustrates that digital transformation remains uneven, highlighting the urgent need for training and capacity-building programs to ensure equitable benefits across all social groups.

Regarding education, most respondents had secondary-level education (junior to senior high school). Despite modest educational backgrounds, they were able to adopt and utilize digital technologies. This suggests that the success of digitalization is not determined solely by formal education levels, but also by access to infrastructure, user-friendly applications, and social support from communities and local governments.

Environmental impacts also emerged as a key aspect of the findings. In agriculture, soil sensors reduced excessive chemical fertilizer use, fostering environmentally friendly practices. In fisheries, catch-monitoring applications helped prevent overfishing, thereby preserving marine ecosystems. Thus, digital transformation offers not only economic benefits but also substantial potential in supporting environmental sustainability.

Overall, the findings suggest that digital transformation in Polewali Mandar represents a strategic opportunity to strengthen food security, improve community welfare, and preserve natural resource sustainability. However, challenges such as uneven internet infrastructure, low digital literacy in certain groups, and limited initial capital remain significant barriers. With stronger government policy support, private sector collaboration, and educational institution involvement, digital transformation in Polewali Mandar's agricultural and fisheries sectors can develop more optimally and serve as a model for other regions in achieving sustainable economic development.

B. Digital Transformation of the Agriculture and Fisheries Sector for Sustainable Economic Development

The findings reveal that the adoption of digital technologies in the agricultural and fisheries sectors of Polewali Mandar Regency has had a significant impact on improving productivity, distribution efficiency, and community income. These results are consistent with the literature indicating that digitalization can serve as a catalyst for enhancing production systems and supply chains in primary sectors (Wolfert et al., 2017; Klerkx et al., 2019).

In agriculture, farmers who utilized weather prediction applications, soil sensors, and digital marketplaces experienced productivity increases of up to 14–16 percent. This demonstrates that digital technologies address key challenges faced by farmers, namely climate uncertainty and limited market access. More accurate weather forecasts enabled farmers to adjust planting schedules appropriately, reducing crop failure risks and stabilizing production. Meanwhile, digital marketplaces shortened distribution chains, allowing farmers to secure higher selling prices. These findings reinforce the view that digitalization is not only technical but also economic in nature, strengthening farmers' bargaining power in the market.

The fisheries sector showed a similar trend. Fishers using digital tools such as GPS, weather monitoring applications, and digital cold chain systems gained dual benefits: improved catch efficiency and reduced operational costs. Research data indicated that post-harvest losses decreased from 27 percent to 18 percent, while digital fishers' monthly income rose by IDR 1.5–2 million compared to traditional fishers. This confirms that digitalization in fisheries enhances productivity, improves product quality, and expands market access. According to FAO (2020), digitalization in fisheries is crucial to reducing post-harvest losses and supporting marine resource sustainability—an impact now beginning to be observed in Polewali Mandar.

From a social perspective, the study highlighted a clear digital adoption gap. Younger generations (20–40 years) were more adaptive to digital applications, whereas older generations (>50 years) tended to rely on traditional methods. Education levels also played a role: respondents with secondary education (junior to senior high school) generally exhibited moderate adoption, while those with higher education tended to be in the high-adoption category. These findings underscore the importance of digital literacy in accelerating

transformation, highlighting the need for training and mentoring programs to ensure more inclusive adoption. From an environmental sustainability perspective, the use of soil sensors in agriculture helped reduce excessive chemical fertilizer usage, while catch-monitoring applications supported fishers in avoiding overfishing. Thus, digitalization can be regarded not only as an economic improvement strategy but also as a means of promoting sustainable development.

However, the study also revealed several limitations. Uneven internet infrastructure in remote villages and coastal areas poses a major barrier to expanding digitalization. Low digital literacy among older generations and limited capital to access modern devices also remain significant challenges. Without adequate support from government policies, the private sector, and educational institutions, the benefits of digital technologies risk being concentrated among certain groups only.

In conclusion, the discussion highlights that while digital transformation in Polewali Mandar has already yielded positive results, it remains in its early stages and is not yet optimal. Cross-sectoral collaboration is required to overcome barriers and broaden the impact of digitalization. If such efforts are realized, digital transformation will become a key driver in strengthening agriculture and fisheries while advancing sustainable economic development in Polewali Mandar Regency.

CONCLUSION

This study demonstrates that digital transformation has had a positive impact on the agricultural and fisheries sectors in Polewali Mandar Regency. In agriculture, the use of weather prediction applications, soil sensors, and digital marketplaces has increased rice productivity by 14–16% and strengthened farmers' bargaining power in the market. In fisheries, the adoption of GPS, weather monitoring systems, and digital cold chain technology reduced post-harvest losses from 27% to 18% and increased the monthly income of digital fishers by IDR 1.5–2 million compared to their traditional counterparts. From a social perspective, digital adoption was more prevalent among the productive age group (20–40 years) and respondents with secondary to higher education, while older and less-educated groups still faced challenges in utilizing technology. This indicates the presence of a digital literacy gap that must be addressed to ensure equitable distribution of digital benefits.

From a sustainability standpoint, digitalization has contributed to reducing excessive chemical fertilizer use in agriculture and preventing overfishing in fisheries. Thus, digital transformation in Polewali Mandar has not only enhanced economic outcomes but also supported environmental conservation.

Nevertheless, the research also identified several barriers, including limited internet infrastructure, low digital literacy in certain groups, and insufficient capital to purchase modern technologies. Therefore, while digital transformation has already delivered tangible benefits, ensuring its sustainability and inclusiveness requires continued support from multiple stakeholders, including government, private sector, and educational institutions.

Recommendations

Based on the research findings, several strategic recommendations are proposed to strengthen digital transformation in the agricultural and fisheries sectors of Polewali Mandar Regency:

Local Government should expand digital infrastructure, particularly by ensuring equitable internet access in inland and coastal areas, as well as organize inclusive digital literacy training programs for all age groups.

Farmers and Fishers are encouraged to be more proactive in adopting digital technologies, such as weather prediction applications, GPS, digital marketplaces, and cold chain systems. The establishment of digital communities or cooperatives can strengthen collective efforts, reduce costs, and enhance access to technology and market bargaining power.

Private Sector and Agritech Startups are expected to develop technologies that are locally relevant, accessible, and affordable. The expansion of digital marketing platforms that connect producers directly with consumers should also be prioritized to broaden market access for agricultural and fishery products.

Educational Institutions and Academia play a vital role through further research, curriculum updates aligned with the digital era, and community service programs that provide direct assistance to accelerate digital literacy at the grassroots level.

Through synergy among government, communities, the private sector, and educational institutions, digital transformation in Polewali Mandar can be optimized to improve productivity, income, market access, and food security, while also supporting sustainable economic development at both the local and national levels.

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