



Digital Transformation Model in Empowering Seaweed Farmers: A Multi-Site Study in South Sulawesi Production Centers

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ABSTRACT

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This study aims to analyze the digital transformation model in empowering seaweed farmers in South Sulawesi's production centers, with a focus on its impact on increasing productivity, market access, and farmer welfare. This study uses a descriptive-qualitative approach with Jeneponto Regency as the main seaweed production area. Data collection was conducted through in-depth interviews, participant observation, and document analysis. The results show that the application of digital technologies, such as e-commerce platforms, farm management applications, and the use of social media for marketing, has a significant impact on expanding market networks and increasing production efficiency. However, the main challenges faced include limited digital literacy of farmers and access to technological infrastructure. This study recommends strengthening digital training programs, collaboration with the government and the private sector, and the development of locally based applications that suit the needs of seaweed farmers. With the implementation of the right digital transformation model, empowering seaweed farmers can encourage local economic growth and support sustainable development in coastal areas.

Keywords: Digital Transformation, Farmer Empowerment

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INTRODUCTION

South Sulawesi is one of the largest seaweed production centers in Indonesia, contributing 25% of total national production (Syaqawi et al., 2023). According to data from the South Sulawesi Maritime Affairs and Fisheries Agency, the province's seaweed production reached 3.2 million tons in 2023, a 15% increase from the previous year (Hamzah & Rasyid, 2024). This advantage is supported by ideal geographic conditions, with a coastline of 2,500 km and water characteristics suitable for the cultivation of *Eucheuma cottonii* and *Gracilaria* sp. (Nurdin et al., 2023). Furthermore, optimal water quality with an average temperature of 27-30°C and a salinity of 28-34 ppt makes this region highly productive for seaweed cultivation (Nurdin et al., 2023). Seaweed production potential is spread across several districts, with the main centers in Takalar, Luwu, Jeneponto, and Pangkep contributing 80% of the province's total production (Rahman & Abdullah, 2024). These four regions have distinct characteristics in terms of cultivation methods, developed varieties, and established supply chain systems (Rahman & Abdullah, 2024). Meanwhile, Jeneponto Regency is famous for its floating raft method adapted to strong current conditions, producing seaweed with a high carrageenan content (Hamzah & Rasyid, 2024).

Pangkep Regency, with its island-like characteristics, has developed an offshore

aquaculture system that enables large-scale production. This region also boasts a unique distribution system based on organized fishing groups, enabling efficiency in the supply chain from islands to processing centers (Rahman & Abdullah, 2024).

Each seaweed production center in South Sulawesi faces different challenges in developing its business. Takalar Regency faces price fluctuations and dependence on middlemen, but has significant potential for direct export development due to improved infrastructure (Nurdin et al., 2023; Asmidar & Kasim, 2023). Furthermore, this region has potential for developing seaweed cultivation-based ecotourism, which could increase added value for coastal communities (Latif et al., 2024). Jeneponto Regency, located on the southern coast of South Sulawesi Province, is one of Indonesia's major seaweed-producing regions. This region holds significant potential for marine and fisheries development, particularly in seaweed, thanks to its relatively clean waters, stable salinity levels, and favorable ocean currents for the growth of *Kappaphycus alvarezii* and *Eucheuma spinosum*. This coastal environment is a key factor in Jeneponto's position as a productive seaweed cultivation center in eastern Indonesia. Despite its significant natural advantages, Jeneponto still faces various challenges that hinder the increase in added value of its production. One major issue is limited access to business capital. Most seaweed farmers are small-scale entrepreneurs who still rely on traditional capital systems, such as loans from middlemen or informal institutions. This situation makes it difficult for farmers to innovate or invest in more modern production facilities and infrastructure.

Furthermore, limited post-harvest technology is also a significant obstacle. Modern drying facilities, proper storage systems, and harvest processing equipment are still very limited. Consequently, the quality of the seaweed produced is suboptimal and its selling price is relatively low. The rudimentary processing process also prevents farmers from gaining significant added value from their crops.

In the context of digital transformation, farmers' literacy and capacity to utilize information technology remain low. Many farmers are unfamiliar with using digital tools for marketing, production management, or accessing information on prices and market demand. This presents a challenge to implementing a digital transformation model to empower seaweed farmers in Jeneponto. Nevertheless, the potential for development in this region remains enormous. According to Rahman and Abdullah (2024) and Mustarim and Yusuf (2023), Jeneponto has a strategic opportunity to develop into an integrated seaweed processing center, particularly with the planned development of a maritime industrial zone in the region. This industrial zone is expected to become a hub for innovation and industrialization in the marine sector, including the processing of seaweed into various high-value derivative products such as carrageenan, agar-agar, and bioplastics.

Regional government support for this sector is also quite strong. Various coastal community empowerment programs, cultivation technology training, and partnerships with the private sector and higher education institutions demonstrate a strong commitment to strengthening the capacity of seaweed farmers. Synergy between the government, communities, and the business world is expected to accelerate the process of coastal economic transformation based on innovation and digital technology. By leveraging its abundant natural resource potential, strengthening institutional support, and integrating digital technology into every stage of production, Jeneponto Regency has a significant opportunity to become a model for sustainable coastal economic development in eastern Indonesia. Implementing this strategy will not only increase farmer productivity and welfare but also foster an inclusive, adaptive, and highly competitive maritime economic ecosystem. The novelty of this research lies in its effort to integrate the concept of digital transformation into the empowerment process of seaweed farmers in coastal areas, particularly in Jeneponto Regency, South Sulawesi. Unlike previous studies, which generally focused on the technical aspects of cultivation, increasing production, or strengthening farmer institutions, this study emphasizes how the use of digital technology can be a strategic instrument in increasing productivity, expanding market access, and improving farmer welfare. Another novelty arises from the approach that simultaneously combines social, economic, and technological dimensions, while taking into account the local characteristics of coastal communities that still have limited digital literacy and access to infrastructure. Thus, this

research offers a new perspective on digital transformation that is not solely oriented towards technology, but also focuses on aspects of empowerment and social inclusivity. This research also addresses a significant gap in the literature on digitalization in the marine and fisheries sector. Most previous studies have focused on digitalization in the context of inland agriculture, such as rice and horticulture, while the seaweed cultivation sector has received little attention. However, the nature of the seaweed business, which relies on marine ecosystems, weather, and global market networks, requires a different and more adaptive digital transformation model. Furthermore, research on the application of digital technology in Indonesia's eastern coastal areas, including Jeneponto, remains limited, despite the region's significant potential to become a center for integrated seaweed processing. Another gap lies in the lack of studies linking digital transformation to the social empowerment of farmers. Some existing research still views digitalization solely as the use of tools or applications, ignoring the socio-cultural factors and human resource readiness that influence its successful implementation. This study aims to bridge this gap by offering a contextual and applicable digital transformation model that considers not only technological availability but also local social, economic, and institutional readiness to support the sustainable empowerment of seaweed farmers. Thus, this study makes an important contribution to broadening understanding of how digital transformation can be implemented effectively.

METHOD

This research employs a qualitative approach with a multi-site study design, allowing researchers to deeply explore the phenomenon of digital transformation in empowering seaweed farmers across multiple locations. This approach was chosen because digital transformation is not simply a technical change but also involves complex social, economic, and cultural aspects that are difficult to measure quantitatively. According to Creswell & Poth (2022), a qualitative approach is particularly appropriate when the research objective is to understand the meanings, experiences, and perceptions of individuals or groups within their natural context. In the case of seaweed farmer empowerment, this approach allows researchers to capture the nuances of social interactions, traditional practices combined with digital technology, and local dynamics that shape the success or barriers to digital innovation adoption.

The multi-site study design offers the added benefit of comparing similar phenomena across locations, identifying common patterns, and understanding variations arising from differences in social, cultural, and infrastructural contexts. This design allows the research to yield not only a rich understanding of a single community but also broader insights into the factors influencing the success of digital transformation in different coastal areas, such as differences in digital literacy levels, access to technology, and institutional support in each location.

Philosophically, this research utilizes the social constructivism paradigm, which emphasizes that social reality is formed through social interactions and collective interpretations. In the context of digital transformation, social constructivism helps understand that technology implementation is not universal, but rather influenced by the perceptions, experiences, and interactions between farmers, facilitators, government, and market actors. For example, how farmers interpret the benefits of e-commerce platforms or farm management applications is heavily influenced by their experiences, local norms, and social practices prevailing in their respective communities. Using a qualitative approach, multi-site design, and a social constructivism paradigm, this study was able to produce an in-depth and holistic understanding of the digital transformation process, supporting and inhibiting factors, and its implications for the productivity, welfare, and empowerment of seaweed farmers. This approach ensures that the research findings are not only descriptive but also explain the meaning and social dynamics underlying the adoption and implementation of digital technology in the local context. The research subjects in this study included key stakeholders in the seaweed value chain in four main production centers of South Sulawesi, namely seaweed farmers, traders, collectors, processors, and fisheries extension workers. The selection of these subjects was based on the principle that each actor in the value chain has a unique role and perspective in the process of seaweed production,

Patterns and Characteristics of the Seaweed Business Value Chain

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Arungkeke District is one of the areas in South Sulawesi with significant potential for seaweed cultivation. Arungkeke's vast coastal waters and favorable environmental conditions make it a center for seaweed cultivation, particularly for the *Kappaphycus alvarezii* species. Seaweed in this region not only serves as a primary source of livelihood

for coastal communities but also serves as an alternative source of income when fishing activities face constraints. However, despite the significant potential for cultivation, land use and productivity remain suboptimal. For example, of the potential 8,150 hectares of cultivation area, only about 1,723.8 hectares are utilized, resulting in a production of approximately 14,892 tons. This indicates a gap between the potential and realization of seaweed cultivation in Arungkeke District. The stages in the seaweed business value chain in Arungkeke can be described as pre-production, production, distribution, processing, and marketing. In the pre-production stage, farmers prepare seaweed seeds, frames or nets, and other cultivation tools. The production stage includes planting, maintenance, harvesting, drying, and sorting. These activities are largely carried out traditionally, involving family labor, with women often assisting at specific stages such as arranging the seeds or drying. After harvest, the seaweed is usually sold to collectors or village traders before finally reaching wholesalers or exporters who distribute it to domestic and international markets. Further processing, such as the production of carrageenan flour or other processed products, is still limited at the local level, so the added value obtained by farmers is relatively low compared to traders or exporters. The characteristics of the seaweed business value chain in Arungkeke show a fairly traditional pattern, with a long chain and margins concentrated in traders or collectors. Farmers achieve limited added value because most activities are limited to drying and basic cleaning. Suboptimal institutions, including the lack of formal contracts or strong farmer groups, make coordination between value chain actors inefficient and farmers' bargaining power weak. Furthermore, seaweed cultivation is highly dependent on aquatic environmental conditions. Studies show that water quality in several Arungkeke cultivation sites is affected by shrimp pond waste, increased epiphyte growth, and other environmental factors that impact seaweed growth and quality. These conditions increase the vulnerability of seaweed farming to external factors and pose production risks.

Research findings and similar literature indicate that this traditional seaweed value chain pattern has significant implications for farmer welfare. The added value that could be obtained through processing or direct marketing is difficult to achieve due to limitations in technology, market access, and capital. Studies in other areas, such as Takalar and Pangkep, indicate that the largest profit margins are usually earned by wholesalers or collectors, while farmers receive only a small portion of the total value. This highlights the need for institutional strengthening and farmer access to markets to enable them to capture a greater share of the added value. Despite facing various obstacles, the seaweed business in Arungkeke remains highly potential. By strengthening local processing, improving cultivation quality, and improving market access, farmers can increase added value and income. Improving post-harvest infrastructure, such as proper drying facilities and proper packaging, can also help improve product quality and make it more competitive in the market. Furthermore, improved environmental management is crucial for maintaining sustainable production, as the sustainability of cultivation is highly dependent on water quality and coastal ecosystem conditions.

Overall, the seaweed business in Arungkeke District has a long and traditional value chain pattern, with added value still largely concentrated among traders or collectors. Farmers are in the upstream position with relatively small margins due to limitations in processing, direct marketing, and institutional arrangements. To improve farmer welfare and seaweed competitiveness, efforts are needed to strengthen institutions, develop local processing, improve post-harvest quality, expand market access, and manage the environment sustainably. Studies related to the seaweed value chain in South Sulawesi include Syafiuddin and Malik (Octopus Journal), Yulisti et al. (Journal of Maritime and Fisheries Socioeconomics), Athirah et al. (Journal of Maritime and Fisheries Socioeconomics), and Nadir (2023) regarding the impact of shrimp pond waste in Arungkeke. Additional references can be obtained from official sources of the South Sulawesi provincial government regarding seaweed potential.

Potential in Implementing Digital Transformation in Various Production Centers

Arungkeke District in Jeneponto Regency is one of the main seaweed cultivation areas in South Sulawesi, with physical and socioeconomic conditions that support the development of this business. The majority of seaweed farmers in this region still use traditional methods, resulting in relatively low productivity and business efficiency. Research by Athirah et al. (2020) shows that farmers' education levels are still low, their incomes are largely limited, and access to market information and technology is also very minimal. The marine environment in Arungkeke is quite supportive for the cultivation of *Kappaphycus alvarezii* seaweed because the seabed consists of coarse sand or coral rubble, the currents are relatively moderate, and the water salinity is quite stable, as explained by Yusuf (2013) in his analysis of the sustainability of seaweed cultivation in Jeneponto.

In the context of digital transformation, the potential is enormous. The use of digital technology in seaweed cultivation can facilitate the collection of production data and real-time monitoring of environmental conditions. Internet of Things (IoT)-based sensors can be used to monitor water quality, salinity, and other environmental parameters that affect seaweed growth, thereby minimizing the risk of crop failure. Environmental conditions that are vulnerable to pollution, for example from waste from super-intensive shrimp farms, make the use of digital technology highly relevant for detecting environmental changes more quickly and responding appropriately. Digital Transformation also has the potential to improve market access for farmers. Seaweed marketing in Arungkeke has previously relied heavily on local collectors, often resulting in farmers receiving lower prices than market value. With digital platforms, social media, and marketplaces dedicated to marine products, farmers can sell their products directly to consumers or processing industries, expanding their market network and increasing income. The use of digital technology also enables the integration of processing processes at the local level, which has previously been limited. Digital-based information systems can facilitate product quality tracking, production management, and post-harvest processing, increasing the added value of seaweed and making the value chain more efficient.

Digital transformation also supports the strengthening of farmer institutions and production governance. With a digital information system, farmer groups can be better organized, monitor production, and access transparent price and market demand data. This enables farmers to negotiate better with collectors or distributors, and optimizes coordination among group members. However, the implementation of digitalization in Arungkeke faces several challenges. Digital infrastructure, such as a widespread internet network and adequate technological devices, remains limited. Human resource capacity is another constraint, as most farmers are unfamiliar with digital technology and require training. Furthermore, the dynamic marine environment requires robust and responsive digital systems, while local institutions and business capital remain relatively weak.

Overall, this study demonstrates the significant potential for implementing digital transformation in the seaweed production center of Arungkeke District. Digital technology plays a crucial role in improving production efficiency, product quality, marketing, and institutional strengthening, thereby increasing farmer incomes and the competitiveness of local products. Realizing this potential requires infrastructure support, training, capital, and government policies that support technology adoption at the local level.

References that serve as a reference for this research include Athirah, Admi; Asafa, Ruzkiah; Paenaa, Mudian in "Exploratory Study of Socio-Economic Conditions of Seaweed Cultivation Community in Arungkeke District, Jeneponto Regency, South Sulawesi" published in *SIGANUS: Journal of Fisheries and Marine Science*, 2020; Yusuf, Nur Rahmah, "Sustainability Analysis of *Kappaphycus alvarezii* Seaweed Cultivation in Binamu District, Jeneponto Regency," Hasanuddin University Thesis, 2013; Rangka, Nur Ansari, "Impact of Changes in Salting Business to Seaweed Cultivation in Coastal Communities: Case Study in Jeneponto and Maros Regencies, South Sulawesi," *FITA Proceedings*; Mahatama, Erizal; Farid, Miftah, "Competitiveness and Marketing Channels of Seaweed: Case of Jeneponto Regency, South Sulawesi," *Scientific Bulletin of Trade Research and Development*; Hasriyanti, "Mapping of Seaweed Production Areas in Tamalatea District, Jeneponto Regency," *Sainsmat Journal*, 2014; and several national proceedings and articles on digitalization in agricultural

Adaptable Digital-Based Empowerment Model

The research results show that the implementation of digital-based empowerment in Arungkeke District has enormous potential, but also faces various structural and cultural challenges that affect its success. In general, the Arungkeke community has entered the early stages of technology adoption, marked by increasing smartphone ownership and social media use, but the level of technology utilization for productive purposes remains relatively low. This condition aligns with Nasution's (2020) findings that rural communities in Indonesia are generally in the basic adoption phase, namely the stage when technology is used for communication but not yet used for value-added economic activities (Nasution, 2020).

In the Arungkeke context, digital technology utilization remains limited to familiar communication activities such as WhatsApp and Facebook. Field observations indicate that communities, particularly farmers and fishermen, do use smartphones to search for weather or commodity price information, but have not yet utilized digital agricultural applications, online marketing platforms, or electronic financial services. This situation emphasizes the importance of digital literacy as a primary requirement for productive technology use. This aligns with Purnomo et al.'s (2020) view that digital empowerment cannot succeed without a digital needs assessment and gradual community capacity building (Purnomo et al., 2020).

One of the main issues identified in the research is the inadequate quality of digital infrastructure. Several hamlets in Arungkeke District still experience limited signal or unstable connections. This makes it difficult for residents to use big data-based applications and hinders the digital learning process. This finding is consistent with Fatmasari (2021), who emphasized that infrastructure is a determining factor in the success of digital transformation in rural areas (Fatmasari, 2021). Limited infrastructure also directly impacts the community's low motivation to utilize technology optimally because digital access is unreliable at all times. Beyond infrastructure, digital literacy in the Arungkeke community is relatively low, especially among middle-aged and older farmers, fishermen, and MSMEs. Many still view technology as complicated and intended only for young people. In-depth interviews indicate that the community prefers face-to-face learning with live demonstrations over digital module-based learning. This finding aligns with Astuti's (2022) recommendation, which states that hands-on learning is more effective in improving digital literacy in rural communities (Astuti, 2022).

Research also reveals that digital empowerment is more effective when using a community-based empowerment approach. This is evident in the involvement of local youth, who possess superior digital skills compared to other generations. Arungkeke youth act as local facilitators, teaching other residents how to use simple digital applications, particularly for marketing local products. This approach has been proven effective in several digital empowerment programs in other regions, as noted by Yusriani (2023), who notes that the role of local digital volunteers can increase the effectiveness and sustainability of digital literacy programs (Yusriani, 2023). Furthermore, research results show that the Arungkeke community responds positively when digital empowerment models are tailored to their economic activities. For example, in the MSME sector, residents are more receptive to training on creating simple promotional content using mobile phones than to technical training like website creation. Similarly, farmers are more enthusiastic about using weather prediction and harvest recording apps than e-commerce applications. This phenomenon aligns with the Smart Village principle, which states that village digitalization must be oriented towards the real needs of the community and utilize technology relevant to local socio-economic conditions (Rahman, 2021).

Overall, the results of this study demonstrate that digital-based empowerment in Arungkeke District requires not only technology but also a digital cultural transformation. This cultural change includes increased digital skills, trust in technology, understanding the benefits of the digital economy, and social support from the surrounding community. This aligns with Community Informatics theory, which emphasizes that technology will be

effective when used within a community context with supportive social and cultural capacities (Gurstein, 2014).

This research demonstrates that the success of the digital empowerment model in Arungkeke relies heavily on three key components. First, improved digital infrastructure that enables stable internet access throughout the hamlet. Second, a sustainable digital literacy program based on hands-on, contextualized practice. Third, community mentoring through local digital activist groups consisting of youth, volunteers, and community leaders. These three components are interconnected and serve as the primary foundation for building an inclusive and sustainable digital ecosystem in Arungkeke District.

Thus, the results of this study confirm that digital-based empowerment in Arungkeke District is not simply the introduction of technology, but a process of social transformation that requires adaptive, collaborative, and locally value-oriented strategies. If these three aspects are met, digitalization has real potential to advance the welfare of the Arungkeke community.

CONCLUSION

The Digital Transformation Model for Empowering Seaweed Farmers in various seaweed production centers in South Sulawesi demonstrates that digitalization plays a strategic role in increasing farmer capacity, efficiency, and competitiveness. Digital transformation not only improves technical aspects of production but also changes the patterns of farmer interaction with information, markets, and supporting institutions. First, the research revealed that most seaweed farmers have begun to have access to digital devices such as smartphones, but their utilization remains at a basic level. Technology is primarily used for communication, while the potential for utilizing production applications, marketing platforms, water quality analysis, and digital financial services is not yet optimal. This indicates that digitalization is still in the "surface adoption" phase and has not yet fully become part of the seaweed farming management system.

Second, an effective digital transformation model must consider the characteristics of coastal ecology, farmer work patterns, and digital literacy capacity in each location. Research has found that differences in social characteristics and digital infrastructure in Arungkeke District, Jeneponto Regency, mean that digitalization needs vary across regions. Therefore, a multi-location approach helps build a model that adapts to variations in local contexts. Third, digitalization has had a significant impact on increasing farmers' knowledge regarding market prices, weather forecasts, water quality, and cultivation techniques. The use of digital channels such as WhatsApp, Facebook, and weather apps has proven to accelerate the flow of previously limited information. This impact aligns with the concept of smart fisheries and aquaculture, where data integration forms the basis for farmers' decision-making. Fourth, collaboration between local governments, universities, farming communities, and village youth plays a significant role in accelerating the digital transformation process. Continuous mentoring has proven more effective than short-term training. Therefore, the success of a digital transformation model is determined not only by technology but also by a supportive social ecosystem that acts as a bridge for technology absorption.

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