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# MAPPING ENABLERS AND CHALLENGES OF TILAPIA WOMEN FARMERS IN ENHANCING FOOD SECURITY THROUGH ACCELERATED DIGITAL TRANSFORMATION IN SLEMAN REGENCY, SPECIAL REGION OF YOGYAKARTA, INDONESIA

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## ABSTRACT

This study investigates the enablers and challenges of digital transformation for women tilapia farmers in Sleman Regency, aiming to understand its role in enhancing food security. The research employed qualitative approaches, including document analysis, focus group discussions, and in-depth interviews with 28 informants, conducted in Sleman Regency, Yogyakarta, Indonesia. Findings reveal that women farmers in the 'Mina Mandiri' group effectively leverage digital technologies to boost productivity and market. Key enablers include strong support from local resources, family, and community networks. Despite these enablers, they are still facing structural hurdles, including restricted access to education, inadequate computer literacy, and the absence of gender-responsive regulations, compounded by cultural impediments associated with gender roles and male dominance in the sector. The study underscores the critical need for gender-responsive strategies to overcome these obstacles and fully harness the potential of digital transformation, thereby significantly enhancing food security through the empowerment of women tilapia farmers.

**Keywords**: Rural Women; Aquaculture; Women Empowerment; Digital Transformation; Yogyakarta

## INTRODUCTION

The tilapia culture sector plays a crucial role in enhancing food security, fostering economic development, and improving community welfare (Gichuki *et al*., 2024), directly affecting the improvements in local dietary patterns, nutritional status, health outcomes, and increased community resilience (Hernández-Sánchez & Aguilera-Morales, 2012; Nguyen *et al*., 2022). The aquaculture sector facilitates local economic development through job creation in fisheries, management, and distribution (Harohau *et al*., 2020).

Several aspects of aquaculture that are of interest include the participation of women in aquaculture activities, as well as the gender dynamics that exist in broodstock management, the hatchery and nursery phase, the grow-out phase, and marketing and distribution (Galiè *et al*., 2019; Shanta *et al*., 2025). Women continue to play a vital role in the fisheries industry in several countries, including Nigeria, India, Bangladesh, the Philippines, and Indonesia, despite facing gender disparities in terms of asset ownership and income (Gopal *et al*., 2020; Islam, 2024; Omeje *et al*., 2021; Shanta *et al*., 2025).

Women are often underrepresented in the more technical and capital-intensive stages of aquaculture (Awuor, 2021; St. Louis & Oliveira, 2020). Women do, however, participate in fish management activities, which may include jobs in the hatchery and nursery phases. In Nigeria, they help with fish management, liming, and grading (Omeje *et al*., 2021). Meanwhile, women in Bangladesh perform a variety of aquaculture duties, including those associated with the hatchery and nursery phases (Islam, 2024). Furthermore, women play a key role in the grow-out period, particularly in homestead aquaculture. In Bangladesh, 89% of women work in household aquaculture, including the grow-out phase (Siddiqa *et al*., 2017). In Thailand and Indonesia, women are routinely involved in the daily management of fish farms (MFF, SEI, & SEAFDEC, 2018).

Prioritizing the empowerment of women is a key strategy for managing a sustainable, productive, inclusive, and efficient tilapia farming business (Aung *et al*., 2021; Galiè *et al*., 2019). Women participate in multiple stages of tilapia farming, including pre-production, production, and post-production. Participation in aquaculture has a positive influence on the well-being of individuals and the community, reflecting their economic and social status (Galiè *et al*., 2019; Shanta *et al*., 2025). Women's active involvement in decision-making processes and the increase in household income can strengthen community resilience (Shanta *et al*., 2025).

Digital transformation in aquaculture can empower women by integrating data into their operations, promoting sustainable practices. This can lead to economic empowerment, increased income, and social sustainability (Bachmann *et al*., 2022; Jayasankar *et al*., 2022; Li *et al*., 2025). However, women face challenges in utilizing digital technology for sustainable aquaculture, particularly in rural areas. Limited



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access and societal labeling often hinder their participation in digital inclusion efforts (Gupta & Kiran, 2025; Jayasankar *et al*., 2022; Novo-Corti *et al*., 2014). Despite these challenges, digital transformation can help reduce resource inequality and improve governance in aquaculture and rural communities.

Misunderstanding women as a uniform group overlooks their diverse experiences, shaped by intersectionality factors like gender, age, race, ethnicity, socioeconomic status, religion, and geographic location (Gonzalez Parrao *et al*., 2021; So, 2024; Wong *et al*., 2022). Digital transformation requires an intersectional approach to address these (Foster & Heeks, 2013). Women face challenges in fulfilling productive roles, including cultural, religious, socio-demographic, and economic factors. Research shows women in Africa and South Asia face similar challenges despite empowerment interventions (Adam *et al*., 2024, 2025; Barak *et al*., 2024; Soh Wenda *et al*., 2024).

The role of women and digital transformation have been widely studied, studies. However, there are limited studies that examine the various opportunities and barriers experienced by women in aquaculture, aiming to reduce poverty and increase food security through digital transition, especially in the context of developing countries (Gopal *et al*., 2020). Consequently, this study aims to identify and address the specific challenges faced by female tilapia farmers in Indonesia regarding access to digital technology, highlighting the vulnerabilities that contribute to gender disparities in the aquatic food system. By examining the role of women in fisheries and the impact of digital transformation on food security, the research seeks to inform the development of gender-responsive policies and interventions. Ultimately, the study advocates for inclusive and equitable support systems that recognize and enhance women's contributions to the aquatic food sector, thereby promoting their active participation in the development process.

## RESEARCH METHODS

### Study Site

The research was conducted at the 'Mina Mandiri' aquaculture group. The group is located in Ngemplak District, which is recognized as part of the Minapolitan Area in Sleman Regency, Special Region of Yogyakarta. In addition, the Mina Mandiri area is currently being developed as a mining tourism zone, further enhancing the region's potential for economic diversification.

Aquaculture in Mina Mandiri, Sleman Regency, has a long history dating back to 1976. Despite the 2010 eruption of Mount Merapi, many residents have remained in agriculture and improved their livelihoods (Kusumasari & Suyatna, 2015).

As agricultural land is converted into residential and commercial areas, diversification into trade and services is encouraged (Azimah & Damayanti, 2019). The Mina Mandiri region, known for its high tilapia production, has 729 aquaculture groups, highlighting the importance of aquaculture in the local economy.

Mina Mandiri's resilient history and diversification efforts make it stand out as one of the leading aquaculture groups in the region. According to the Fisheries Profile of Sleman Regency (2022), it has the most significant number of active members (60 members) and manages a total of 300,000 square meters of aquaculture land. The group specializes in the farming of tilapia, catfish, and goldfish and has received multiple national-level awards in recognition of its achievements in sustainable aquaculture. With a production value ranging from 10 to 500 million rupiah per harvest cycle, it demonstrates collaborative business management and innovation, making it a strategic study site (Azimah & Damayanti, 2019).

### Data Collection Methods

#### Qualitative Approach

This investigation employs a qualitative methodology to explore and understand the interpretations associated with individuals or groups with human social issues (Bell *et al*., 2018; Creswell & Poth, 2018). This methodology is particularly advantageous for researchers, notably academics, in acquiring comprehensive data to elucidate intricate phenomena (Creswell & Poth, 2018).

This qualitative research is an inductive investigation aimed at identifying the agency of female tilapia farmers in their involvement in attaining food security through digital transformation in Sleman Regency. Furthermore, in-depth interviews, focus group discussions, and observations have proved to be reliable methods for collecting rich empirical facts in the fieldwork.

Semi-structured questions were formulated to facilitate in-depth exploration of informants' interpretations regarding social and cultural constructs, and women's agency in advancing food security through digital transformation (Creswell & Poth, 2018).

### Sampling Methods

Data collection for this study was conducted in September 2024. The study involved 28 informants, including three stakeholders (i.e., a local government official, a community leader, and an extension worker) and 25 female tilapia farmers in Sleman Regency, Special Region of Yogyakarta. The stakeholders were chosen to provide a macro or policy and regulation perspective. Respondents were selected using a snowball sampling method, starting with a list provided by the administrators of Mina Mandiri. The method is suitable and effective for identifying participants in a specific, sometimes hard-to-reach, community or group with interconnected networks such as Mina Mandiri.

A total of 25 female respondents were selected from households in which male family members, either husbands or sons, are registered members of the 'Mina Mandiri' aquaculture group. All these women are also registered as active members of the 'Mina Mandiri' fish processing and marketing group, which increases their access to information and networks since they are also a part of the beneficiaries of the extension program.

Although not formally listed as members of the aquaculture group, observations revealed that 17 female respondents actively engaged in various technical aspects of Tilapia farming, including seed stocking, daily maintenance, and product marketing. The remaining eight female respondents, although not involved in core aquaculture operations, still contribute daily through tasks such as collecting tilapia larvae using fine mesh nets, transferring them to nursery ponds, feeding fish, and preparing meals for aquaculture workers.

Qualitative data were collected through interviews and direct observations. The research utilized both primary and secondary data. Primary data were obtained through semi-structured interviews with 25 female respondents guided by interview protocols, focus group discussions (FGDs), and field observations. Secondary demographic data were collected from

relevant government agencies, specifically the Agricultural, Food, and Fisheries Extension Center (Region VI) in Ngemplak District, Sleman Regency.

**Data Analysis Methods**

Miles and Huberman's analysis involves an interactive and ongoing process of qualitative data analysis, culminating in data saturation. Miles *et al*. (2020), suggest that analysis comprises three simultaneous activities: data reduction, data presentation, and conclusion drawing/verification.

Data reduction involves identifying and categorizing major themes, including enablers (potential natural resources, technology development) and obstacles (limited education access, limited infrastructure access) encountered by women tilapia farmers. Data presentation includes organizing and compressing data to make it easier to understand and analyze. In this study setting, data may be displayed in matrices that highlight links between facilitators and challenges across villages or demographic groups. The table illustrates the number and percentage distribution of training services received by Tilapia women farmers. The final step is evaluating the data, creating results or explanations, selecting key points and validating them by looking for consistency, competing explanations, or triangulation. In this case, this study concludes that women have both internal and external enabling capacities, allowing them to respond proactively to digital transformation opportunities in the aquaculture business. But, this potential is accompanied by a number of structural and cultural hurdles that continue to restrict the optimal use of digitalization.

## RESULT AND DISCUSSION

**Demographic Profile of the Respondents**

The data distribution based on age and the percentage of women presented in Table 1 shows that the majority of female respondents are still of productive working age. With a large population of productive age, this area has great potential to develop a more efficient, productive, and sustainable fisheries sector through the use of digital technology. This thereby contributes indirectly to economic development at the regional or national level.

**Table 1.** Distribution of Numbers by Age and Percentage of Women

| Characteristic | Number | Percentage (%) |
|---|---|---|
| Unproductive (<15 years) | 0 | 0 |
| Productive (18-64 years) | 23 | 92 |
| Unproductive (>64 years) | 2 | 8 |
| Sum | 25 | 100 |

Table 2 shows that the education level of women farmers in the Mina Mandiri is relatively low. Although these figures do not represent the educational background of all women in the Mina Mandiri, they provide an overview of the informant profile relevant to digital technology proficiency. This educational background is particularly relevant when considering their proficiency and adaptation to digital technologies, a key focus of this study. These relatively low education levels indicate potential challenges in computer literacy and the adoption of more complex digital technologies.

**Table 2.** Distribution of the Number and Percentage of Women by Level of Education

| Education Level | Number | Percentage (%) |
|---|---|---|
| No school | 3 | 12 |
| Elementary | 2 | 8 |
| Junior High School | 8 | 32 |
| Senior High School | 12 | 48 |
| Diploma/Bachelor's | 0 | 0 |
| Sum | 25 | 100 |

**Enablers of Tilapia Women Farmers in Enhancing Food Security through Digital Transformation**

The presence of enablers or supporting factors plays a vital role in supporting the participation of women tilapia farmers in achieving food security through digital transformation. This study reveals that these factors not only strengthen women's technical capacities but also enhance their social positions, widen market access, and amplify their roles in community decision-making. These enablers are categorized into external and internal dimensions.

**External Factors**

Potential of Natural Resources

The availability and accessibility of natural resources in the study areas, such as freshwater resources and farmlands, are key enabling factors in supporting women's participation in tilapia farming and their broader role in enhancing food security through digital transformation. Living near rivers, farmland, or fishponds creates opportunities for the development of freshwater aquaculture systems that are feasible even with minimal capital and technical inputs. In this digital technology context, the women farmers enter the size of their ponds as the primary input in the data analysis process to obtain the profit calculations.

This environmental abundance significantly lowers structural barriers to entry into aquaculture. Some respondents stated that even if they did not own land, they could still rent from other farmers or build semi-permanent ponds around their yards. In other cases, some respondents utilize their inherited pond infrastructure, family-owned assets passed down through generations, as their current source of livelihood. Local resources such as fish hatcheries, markets, and training facilities help female tilapia farmers manage aquaculture activities. Digital data analysis related to local resource assets can uncover critical patterns, enable targeted interventions, and increase women's autonomy.

From a theoretical standpoint, these findings support an asset-based approach to rural development, which recognizes that natural, physical, and social assets within communities can be mobilized to strengthen livelihood strategies. When paired with digital tools that enhance access to information and market linkages, the potential of natural resources becomes a crucial foundation for transforming inclusive food systems.

Modernization/ Technology Development

The integration of digital technologies in the Tilapia farming value chain is emerging as a transformative driver that enhances women's roles and productivity, as well as the overall sustainability of food systems in rural communities.

The majority of respondents are familiar with digital platforms such as WhatsApp, Facebook, Shopee, and TikTok. Affordable internet (approximately 100,000 rupiah per month) and the availability of Wi-Fi, provided through a local government initiative in Ngemplak District, make digital access more inclusive for all different socioeconomic groups.

Beyond social media, women are also utilizing simple aquaculture technologies, such as mechanized aeration systems (paddle wheels) whose benefits are amplified by a specific application or record-keeping and actively engaging with digital training platforms. Evidence from study sites shows that access to and utilization of aquaculture technologies directly contributes to increased production. Respondents stated that the use of windmills is crucial for enhancing water oxygenation, leading to reduced fish mortality and increased growth rates. This mechanization results in higher yields without requiring extensive manual labor, which is particularly important for women who often balance domestic and productive responsibilities.

Women also see digital bookkeeping tools as very useful for business management functions such as record-keeping. Some respondents, particularly those not directly involved in pond activities, pointed out the importance of record-keeping to track production volumes and sales data. This digital bookkeeping not only facilitates better financial monitoring but also enhances transparency and supports informed decision-making.

Collective Action/ Social Networking

Collective action and social networks among Tilapia women farmers are important supporting factors in driving digital transformation and enhancing food security. In the context of rural aquaculture, women are actively involved in various forms of institutions that cover both social and economic dimensions-from community groups such as recitation, PKK, Posyandu, and PAUD to cooperatives, aquaculture groups, and fishery product processing and marketing groups. Women's active participation in various institutions will create opportunities for their growth, development, and application of their potential in digital technology, allowing them to enhance their economic empowerment and improve their economic and social status.

Community-based organizations such as PKK (Family Welfare Movement), PAUD (Early Childhood Education Centers), and Posyandu (Integrated Health Services Posts) have long been vital sites of social organization, mutual support, and information sharing for women in rural and semi-urban communities. Women farmers meet in these places on a regular basis not just for child care, health education, and family welfare activities, but also for informal discussions, the exchange of local expertise, and the coordination of community efforts. These grassroots networks create a trust-based social infrastructure that may be strategically used to promote collective digital adoption.

Through active involvement in these organizations, women gain more structured access to education and training services, as well as potential sources of financing, all of which are essential elements to support aquaculture productivity and economic empowerment. These institutions also foster a spirit of mutual support that helps overcome limitations in individual access to digital technology. Joint initiatives such as group-based digital literacy training or collective procurement of software demonstrate how shared institutional frameworks can effectively bridge access gaps and promote technology adoption (Saha *et al*., 2024).

The benefits of collective action become even more significant when combined with digital tools, particularly in enhancing market access and visibility. Social media platforms, such as Facebook, have enabled women to connect directly with new customers and trading communities.

*"Before I got sick, I tried selling on Facebook. It was quite profitable. There are many Facebook groups, such as the Sleman or Bantul fish trading communities. Buyers usually arrange their transportation."* – Respondent 1

This example illustrates how digital technology helps women overcome the barriers of traditional markets and build direct relationships with consumers. Previous studies have shown that market access through technology contributes to women's economic empowerment. This reinforces their role as active economic actors, not just producers. Direct access to markets strengthens economic empowerment and enhances women's roles in household and community decision-making. Their confidence in negotiation and participation also grows, encouraging active involvement in farmer groups (Cole *et al*., 2020; FAO, 2023). This statement also aligns with Jayasankar *et al*. (2022), argument that women's participation in public economic activities not only strengthens household economic resilience but also enhances their individual capacity and social status.

**Internal Factors**

Women's Role in Productive Activities

Tilapia women farmers play a significant role in productive activities that contribute to household and community food security. Women tilapia farmers have an important part in all stages of aquaculture, including feeding and harvesting, handling, marketing, and fishery processing, allowing them to observe the direct benefits of digital tools that increase production and market access. Their daily involvement in these productive activities provides a significant motivation to use technologies such as mobile apps for digital bookkeeping and online sales platforms. When given the necessary assistance and training, their active participation in the value chain becomes a major enabler of digital technology adoption.

As expressed by Respondent 2, local expressions such as "*obah ae dadi duit*," which means "if you are willing to move, you will earn money," reflect a community culture that values hard work and collaboration, regardless of gender. This type of community provides a more equitable participation space for women in the productive sector, including in the context of the digital transformation of the fisheries industry. When women feel socially supported, they are more encouraged to develop new skills, utilize technology, and innovate in their fisheries businesses.

The entrepreneurial mindset of women not only signifies their economic independence and commitment to improving family welfare and community resilience but also acts as a cultural basis for adopting technology advancements. Their proactive initiatives to diversify revenue through fish processing, internet marketing, or engagement in cooperative

networks demonstrate a profound culture of adaptation, mutual assistance, and innovation. This cultural inclination fosters an environment conducive to the adoption of digital tools and technology, as women are already adept at devising innovative solutions and utilizing available resources to enhance their lives.

Individual Agency

The proactive involvement of women fish farmers in business management serves as a critical entry point for local women's engagement in the digital transformation process. In Mina Mandiri, several female farmers have demonstrated the ability to face, manage, and overcome various environmental and economic challenges by utilizing local resources, particularly through the farming of tilapia and catfish.

Despite operating with relatively basic technology that aligns with their available skills and financial capacity, these women can sustain and even expand their business productivity. Financial records from Mina Mandiri confirm this resilience and steady growth. Their entrepreneurial success stems not only from resourcefulness but also from strong individual and collective agency. As one of the stakeholders from Mina Mandiri reflected:

*"The establishment of this processing group was purely driven by determination. I see many women fully economically dependent on their husbands. Moreover, the place where they live has high potential. So, I began looking for ways to harness that potential."*

She added: *"I already had good relations with the local fisheries government, so I asked and invited them to teach the women how to process fish into saleable products. From there, I, along with other women from the UPPKA (Usaha Peningkatan Pendapatan Keluarga Akseptor/Family Income Improvement Business) group, attempted to start a business under the name 'Mina Mandiri' fish processing and marketing group, utilizing whatever resources we had available. For example, if one of the members had a small store, we would buy flour and oil from them, and we would also buy fish seeds from their husbands."*

*"We first sold our products at PKK (Pemberdayaan dan Kesejahteraan Keluarga/Empowerment and Family Welfare) gatherings, and the sales were good so that we could repay the loans for raw materials and fish seeds. As our business grew, the Fisheries Government in Sleman took notice and, in 2013, supported us with cooking equipment worth around 20 million rupiah. That equipment increased our production capacity, and in 2014, we finally established a separate production facility."*

These narratives highlight how women's agency drives change. Their ability to identify problems, mobilize local resources, and develop workable alternatives significantly contributes to their digital readiness. As noted by Rahman *et al*. (2024), women with high awareness and agency often become active agents of transformation, able to adapt to innovations, including digital technologies.

In this context, digital transformation is not an abstract goal, but a gradual process rooted in practical adaptations. For example, basic applications for recording raw materials, production results, customer preferences, and sales volumes can significantly improve business efficiency and decision-making. Such tools not only support operational effectiveness but also help women connect with broader networks, including suppliers, customers, research institutions, and local governments, thereby enhancing their access to markets and innovation.

Women who successfully adopt and utilize digital tools become important role models and mentors within their communities. Their experiences encourage other group members to adopt similar technologies collectively. Furthermore, their leadership and collaborative capacity become enabling factors in the broader mastery and use of digital tools across women's aquaculture groups.

High Motivation

The high level of motivation among women tilapia farmers is a fundamental internal driver in the adoption of digital technologies to strengthen food security. This motivation is not solely internal but also grows and is strengthened through sustained engagement in collective institutions and community networks. Women's willingness to engage in new knowledge systems and digital platforms is driven by the collaborative environment created through their participation in local organizations.

The presence of strong community-based leadership, as demonstrated by the figure of the village head's wife, further illustrates how individual motivation can evolve into collective empowerment. Her role in organizing and facilitating digital literacy training, as well as liaising between women's groups and government programs, demonstrates how highly motivated leadership can encourage broader participation. Not only is she a trainer in creative economy initiatives, but she is also a source of inspiration for other women to continue developing their digital skills, regardless of age or time constraints.

However, the research findings also show challenges. High motivation does not always go hand in hand with optimal application of digital skills. Women over 40 years old tend to prioritize production activities, such as fish processing, over continuous learning, which limits the use of digital tools after training. In response, community leaders, the village head's wife of hamlet chief, proactively invited and empowered young women who were not yet part of the institution to participate in the next digital literacy training, thus ensuring sustainability and cross-generational adaptation within the group.

Thus, when high motivation is embedded within a supportive institutional framework and backed by inclusive leadership, women's capacity to adopt digital technology for aquaculture development can significantly improve.

**Challenges Encountered by Female Farmers in Advancing Food Security through Expedited Digital Transformation**

Despite these positive developments and the clear potential for digital tools, women farmers, particularly in developing regions, still encounter a range of persistent challenges that hinder their full participation and benefit from technological advancements. This study identifies two interrelated categories of obstacles: structural and cultural barriers.

Research on the role of digital technology in enhancing food security, particularly in the fisheries sector, remains limited (Kao & Chen, 2024; Steinke *et al*., 2024). The improvement of

food security in the tilapia farming sector via digital transformation is defined as the application of digital technology to enhance the sector's ability to meet food requirements efficiently, effectively, safely, and sustainably (Vărzaru, 2024). Despite its potential, the integration of digital technology in this sector, especially among women farmers, faces significant challenges.

This study examines the lived experiences of women tilapia farmers as they adopt digital tools to enhance food security. Findings from the field suggest that not all women have equal access to or benefit from digital transformation processes. Two interrelated categories of obstacles emerge: structural and cultural barriers. Structural barriers reflect the systemic limitations that rural women face in accessing essential public services, including formal education, digital literacy training, adequate technological infrastructure, financing opportunities, and gender-responsive policies. These issues prevent women from acquiring the knowledge, skills, and resources needed to utilize digital tools effectively in their aquaculture practices.

Meanwhile, cultural barriers manifest through persistent gender norms, the unequal distribution of domestic responsibilities, and entrenched beliefs that portray aquaculture and technology as male-dominated domains. These cultural constraints often result in lower participation of women in decision-making and capacity-building initiatives. Additionally, concerns about trust and security, particularly regarding online financial transactions, further erode their confidence and engagement in digital platforms.

Structural Barriers

Limited Education (Low Digital and Financing Literacy)

The limited access to technology among female farmers with low education levels is one of the main obstacles to improving their productivity and well-being. Additionally, elderly female farmers in rural areas are often excluded from strategic training that could help them enhance their skills and knowledge. The lack of resources and institutional support also poses another challenge for female farmers, preventing them from accessing the technology and information needed to improve their agricultural endeavors.

Based on demographic profile data, the education level of women farmers in the Mina Mandiri is relatively low. This reflects their limited ability to understand and use digital tools beyond basic communication functions. Several respondents admitted that their use of smartphones is limited to making calls and sending messages, with little to no engagement in educational or business-related activities.

Respondent 3 stated:*"I have never explored anything related to aquaculture using my phone. I typically use it only for messaging via WhatsApp and calling with my husband or family."*

These responses indicate a significant gap between the potential of digital tools and the women's ability to use them effectively. Despite respondents expressing their interest in technology, the application of technology in everyday life, such as learning aquaculture practices, remains constrained due to a lack of access to technological knowledge, particularly among pre-elderly and elderly individuals who are unfamiliar with using new technology.

Additionally, the exclusion of women from strategic training opportunities, where only leaders are selected to participate, undermines collective digital empowerment.

Respondent 4 reflected this sentiment: *"The digital technology training typically pertains only to the leader, not to everyone."*

The issue is particularly acute for elderly women in rural areas, who face compounded vulnerabilities due to limited digital access and capabilities. As this study reveals, elderly women are often digitally isolated, which leads to low confidence and a reluctance to engage with digital platforms. These findings are consistent with Nguyen *et al*. (2022) and Mohan *et al*. (2024), who highlights how digital exclusion among older women in rural areas can lead to adverse effects, including reduced mental well-being, lower social connectivity, and hampered contributions to sustainable development.

The problem is reflected in the data shown in Table 3. Tilapia women farmers in Mina Mandiri reported minimal exposure to capacity-building programs: only 88% received a single education service, and 76% attended just one training service in the past year. This lack of opportunity is not necessarily due to their unwillingness but rather the lack of resources and institutional support.

**Table 3.** Number and Percentage Distribution of Training Services Received by Tilapia Women Farmers

| Training Received | Classification | People | Percentage (%) |
|---|---|---|---|
| ≤1 | Low | 22 | 88 |
| 2-3 | Medium | 2 | 8 |
| ≥3 | High | 1 | 4 |
| Sum | | 25 | 100 |

Source: Fieldwork data (2024)

These findings align with previous research by Hossain *et al*. (2020), which suggests that lower levels of education significantly limit an individual's ability to navigate and apply technological functionalities. A case study in Sleman Regency by the same authors, further documented how repeated ICT training failed to yield a long-term impact due to the absence of mentoring and the participants' low digital literacy.

Systemic issues like educational exclusion, poorly targeted training, intergenerational divides, and ineffective program delivery hinder women's agency in empowerment process. Empowerment involves meaningful use and control of technology, focusing on women's lived realities across age groups, languages, and socio-economic backgrounds. This requires a participatory approach, recognizing women as active agents in shaping their digital futures.

Limited Access to Infrastructure

Digital infrastructure access for women in aquaculture is limited not only by a lack of devices or internet connectivity but also by the technology's appropriateness and usability for their specific needs. Many respondents find the complex applications too complex, requiring time and effort that many women cannot afford. This results in gender disparities, as the benefits of digitalization remain unevenly distributed between male and female farmers.

These findings suggest that digital access should not be understood solely in terms of physical infrastructure, such as network coverage or device ownership, but rather in terms of practical usability and its alignment with users' social contexts. Recent studies emphasize that digital transformation must consider the structural vulnerabilities faced by women, including factors such as limited time, lower educational

attainment, and restricted financial resources (Saha *et al*., 2024; Steinke *et al*., 2024; Vărzaru, 2024). Without intentional design that accounts for these constraints, digital tools risk reinforcing existing inequalities rather than alleviating them.

Therefore, numerous proactive measures in digital transformation must be undertaken, including the development of user-friendly applications that are straightforward to implement, supplemented by explicit instructional materials and tools, as well as mentors who consistently guarantee that all individuals are included in the digital transformation process within the food security achievement system that serves all stakeholders (Steinke *et al*., 2024).

Financial Constraints

Many women continue to face severe barriers to accessing formal financial institutions, particularly in rural and low-income regions. This lack of access not only inhibits women's financial autonomy but also hinders their capacity to adopt and use digital technologies that increasingly require financial participation, such as mobile banking, online markets, and digital payment systems.

Access to formal financial institutions remains a challenge for women. Most respondents rely on household income, which often has limited access to formal financing. This challenge is tough for women in low-income households with small-scale businesses, who often lack the collateral or credit history required to access financing schemes for aquaculture improvement. Women frequently do not have collateral connected to property especially in the context of limited or lack of access to property ownership due to strongly established patriarchal norms influencing property rights, inheritance rules, and gender roles. Also, a lack of transparency in bookkeeping between business and personal finances further hinders business growth. Limited financial literacy and lack of confidence in online transactions, stemming from insufficient digital skills, further exacerbate financial constraints.

Government and Institutional Support

The digital transition for women farmers faces significant challenges due to lack of government and institutional support. Centralization of digital initiatives often overlooks local needs, leading to misaligned solutions. Lack of clear, gender-responsive policies and sex-disaggregated data on women's roles and capabilities further hinders targeted interventions. This data gap hinders efforts to create equitable digital ecosystems in agriculture.

Policy-related information and regulatory oversight within the women farmers' collective are primarily centralized under the authority of the village head's wife, who also serves as the leader of 'Mina Mandiri' fish processing and marketing group. As a result, most members remain uninformed about relevant government policies or institutional programs related to digital technology and agriculture. This centralization of leadership has created a dependency that limits the participation and agency of other women in the group, weakening their capacity to engage in decision-making processes and hindering the development of inclusive leadership.

Insufficient institutional support severely restricts the capabilities of women tilapia farmers, especially due to the lack of gender-responsive and inclusive digital technology legislation. The disparity is seen in the insufficient provision of agricultural extension services and digital literacy initiatives specifically designed to address the distinct needs and limitations of women. Multiple policies have not explicitly addressed the roles and requirements of diverse women with varying vulnerabilities in the context of aquaculture.

Moreover, the lack of disaggregated data by gender on digital technology adoption hampers the creation of evidence-based and equitable policies. Respondents in this study highlighted the lack of accessible data or outreach efforts specifically targeting female farmers despite their prominent role in local fish production. These findings align with concerns raised in previous studies, which argue that policy failure often stems from the lack of accurate gender-specific data and insufficient institutional recognition of the social context in which digital tools are introduced (Kruijssen *et al*., 2018).

Cultural Barrier

Gender Norm Barriers

Certain social and cultural practices frequently restrict women's employment opportunities. Women's participation in aquaculture remains significantly constrained by their domestic responsibilities. Many respondents reported that societal expectations bind them to traditional reproductive roles, such as childcare, cooking, and household maintenance. This cultural construction limits their mobility, time, and opportunity to engage in public or economic activities.

For example, Respondent 5 shared: *"Currently, I am unable to participate because my child is still young, so I cannot do additional work in the processing sector (*Mina Mandiri fish processing and marketing group*)."*

This narrative reflects a broader pattern observed among participants, where responsibilities related to fulfilling reproductive roles are prioritized over any form of productive role engagement. The gender roles assigned to women in childcare, caregiving, maintaining cleanliness, and enhancing the aesthetic of the household are cultural constructs within a specific society, commonly termed the 'nature of women' (Jabeen *et al*., 2020; Kruijssen *et al*., 2018). Therefore, socialization regarding gender roles frequently induces feelings of guilt in women who fail to fulfill domestic responsibilities. Women employed outside the home will experience a dual workload.

In contrast, women with more financial wealth often delegate these domestic responsibilities to others, particularly female household assistants, as shared by Respondent 6: *"I employ five men and one woman. The female employee contributes more to household chores as a domestic worker. Usually, she engages in cleaning tasks and prepares meals for the family and staff, so I can focus on handling customized orders from catering services or restaurants and daily orders along with the male employee."*

This contrast highlights the intersection between class and gender, adding to the complexity of inequality. While some women remain trapped in dual roles, others delegate their burdens—often to other marginalized women (female household assistants). These findings are consistent with previous studies that discuss women's dual workload stems from culturally

internalized gender roles (Jabeen *et al*., 2020; Malhotra *et al*., 2024).

Trust and Security Concerns

Trust and security are also important dimensions limiting the adoption of digital technologies by women fish farmers. Most respondents, especially elderly women, expressed concerns about the security of digital transactions and a lack of trust in online platforms, particularly regarding financial activities such as online transactions.

Although there are now many digital applications that are easy to access and operate, many women are still afraid to operate them for the first time. This limited exposure to advanced functionalities, coupled with a lack of technical support for troubleshooting, further erodes their trust in unfamiliar digital platforms, especially for sensitive financial transactions.

These findings highlight the importance of an approach that not only provides infrastructure or technical training but also includes digital education that strengthens the security literacy and trust of users, especially women, who have previously been marginalized in the technology sphere. This approach is necessary for digital transformation to be truly inclusive and empowering.

## CONCLUSION

This research illuminates the significant contributions of women tilapia farmers in Sleman District, Yogyakarta, to enhancing food security through the strategic adoption of digital technologies. Women have both internal and external enabling capacities that enable them to respond proactively to digital transformation opportunities in the aquaculture sector.

However, this potential comes alongside various structural and cultural barriers that still limit the optimal utilization of digitalization. These findings highlight the importance of creating an enabling environment, not only by providing access to technology but also by addressing the social structures and norms that limit women's opportunities for innovation and entrepreneurship.

By addressing the interconnections between gender, digital transformation, and food security, this study expands our understanding of women in the aquaculture sector through an intersectional approach. Women are not a homogenous group; differences in age, socioeconomic background, and geographical conditions greatly influence how they interact with digital technologies. This contextualized understanding is important for designing interventions that are inclusive and sensitive to the needs of women in rural aquaculture systems, such as tailored training programs and flexible digital tools.

Thus, while Tilapia women farmers have shown a strong capacity and determination to drive digital transformation and enhance food security, their efforts require support from gender-responsive policies and community structures.

Ultimately, this research establishes the profound impact of women tilapia farmers in Sleman District, Yogyakarta, on enhancing food security through their strategic adoption of digital technologies, underscoring the imperative for gender-responsive strategies in leveraging technology for sustainable aquatic food systems.

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