Comparative Analysis of Gender Gap in Smart Farming: Analyzing Women's Role in the Development of Sustainable Agricultural Practices in Southeast Asia

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Abstract: *This study analyzes the gender gap in the adoption of smart farming technologies in Southeast Asia, focusing on the roles of women in the development of sustainable agricultural practices. Despite their significant contributions to food security, women in the agricultural sector continue to face barriers such as limited access to land, technology, and decision-making positions. This research utilizes a qualitative approach by conducting a study report based on official documents, news articles, and international legal frameworks, including reports from organizations such as the FAO, ASEAN, and CEDAW. By reviewing relevant literature and policy reports from ASEAN countries, the study investigates how gender dynamics shape women's participation in smart farming, and the obstacles they encounter in accessing advanced agricultural technologies. The findings indicate that (1) women are disproportionately excluded from access to smart farming technologies due to socio-cultural and economic barriers, (2) gender-sensitive policies in agriculture are insufficient in ASEAN countries, and (3) international legal frameworks, such as CEDAW, have not been effectively implemented at the national level to ensure equal access for women in the agricultural sector. The study concludes that while smart farming offers significant potential for sustainable agriculture, the gender gap in access to these technologies remains a major challenge. Recommendations include strengthening the implementation of gender-focused policies, improving women's access to agricultural technologies, and integrating gender-specific training and capacity-building programs into national agricultural strategies.*

Keywords: *Gender gap; Smart farming; Sustainable agriculture; ASEAN; Women farmers*

1. INTRODUCTION

Food security is a fundamental human necessity essential for daily functioning. The right to food and freedom from hunger are universally acknowledged human rights that must be ensured by every nation. Article 25 of the Universal Declaration of Human Rights asserts that every individual is entitled to an adequate standard of living. Incorporating sustenance. Moreover, moms and children possess distinct rights to equitable social protection. (United Nations, n.d.). The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) additionally affirms protection against all types of discrimination directed at women, including in matters of access to food, as justice and equality are essential to fostering a new international economic order that promotes family welfare and community development (United Nations General Assembly resolution 34/180, n.d.). Therefore, the equitable allocation of food is an obligatory obligation under international law for all nations.

Sustainable food production facilitates the attainment of SDG 2 (Zero Hunger) and contributes to fulfilling the nutritional requirements of society. Smart farming and digital innovation represent sustainable agricultural practices that effectively support the maintenance of food production. Technological advancements in smart farming will improve food security amidst extreme weather conditions. Previous research has demonstrated that wise farming fosters an efficient food system, optimizing water utilization and minimizing carbon emissions (Yurembam et al., 2025). In Southeast Asia region, by employing technical advancements like the System of Rice Intensification (SRI) in the Mekong River area, rice yields were able to be boosted by as much as 52%, labor productivity was increased by 62%, and greenhouse gas emissions were reduced, which contributed to the preservation of food security for households in rainfed areas (Mishra et al., 2021).

Smart farming technologies such as IoT, Artificial Intelligence, and the digitalization of agricultural processes and outputs then provide significant benefits for the development of agricultural production and economic growth (Musa & Basir, 2021). Despite this, in order for this technology to be implemented, it is necessary to provide assistance through governmental measures and to develop the capacity of human resources. One of the significant tools that may be used to improve human resources is the promotion

of gender equality. The Sustainable Development Goals (SDGs) can be accomplished with the assistance of smart farming, but the inclusion of women in technical breakthroughs should also be given priority so that women can have equal access to land, technology, and decision-making responsibilities in the modern agricultural sector (Sundram, 2023a). In Southeast Asia, women contribute nearly 50% of the agricultural workforce, demonstrating significant involvement in this sector. More specifically, an average of 45% of the working-age female population (15-64 years old) in the ASEAN region lives in rural areas, which is approximately 107 million women (ASEAN, 2022).

Women play crucial strategic roles in agricultural food security. Women farmers are intensively involved in food production, processing, preparation, and distribution within families, serving as household managers, small business operators, and community mobilizers (Jumiati et al., 2025). Considering their primary role in securing access to consumption. Motherhoods also have greater control over household food management compared to their husbands, thus playing a central role in the sustainability of food security (Fatchiya et al., 2024). Beside consumption management, women drive climate-smart practices such as crop diversification and the adoption of resistant varieties (ASEAN, 2022).

However, women face significant challenges including limited access to productive resources, technology, and training, which are exacerbated by climate change impacts. ASEAN and OECD (2021) found out that rural women in ASEAN countries face significant difficulties in participating in training or other networking events, reflecting various access barriers such as excessive domestic responsibilities, travel difficulties, financial constraints, discriminatory social norms, and a lack of information about available opportunities. Excessive unpaid workload is a major factor explaining the underrepresentation of women in paid work activities in rural areas. The time women spend on unpaid care work ranges from two and a half to ten times more than men in the ASEAN region.

Despite women can drive climate-smart practices such as crop diversification and the adoption of resistant varieties, yet based on the data above they receive less technical information and limited access to tools compared with men. The goal of this research is to conduct an analysis of the gender gap that exists in the implementation of smart agricultural practices in Southeast Asia. The emphasis of this research is on the function that women serve in the adoption of smart farming in Southeast Asia, as well as the role that the law plays in backing up policies that are able to strengthen the activities and responsibilities that women have in the Southeast Asian region.

2. MATERIALS AND METHODS

2.1. Research Design

This study employs a qualitative methodology grounded in document analysis. The approach is frequently employed to examine written materials, including archives, reports, regulations, news articles, and policies, as well as visual documents like photographs, videos, and dynamic digital sources (Morgan, 2022). This approach is highly appropriate for policy studies as it provides a systematic and adaptable framework for examining the roles of women and smart farming in Southeast Asia through various sources. The analytical process generally has three phases, as outlined below:

1. Selection of Documents:
   Relevant documents are selected, and their data authenticity and validity are verified prior to conducting thematic and interpretive analysis;
2. After the data has been selected, it is processed using the READ method, which is an abbreviation for the phrase Ready Materials, Extract Data, Analyze Data, and Distil Findings. After the materials have been selected, they are then extracted for the purpose of conducting research (Extract Data). After the data has been extracted, it is analyzed using a process called interpretation and grouping (Analyze Data). This process is intended to produce findings and conclusions regarding the analysis results (Distil Findings) process (Dalglish et al., 2020).

2.2. Types and Origins of Data

This study employs secondary data sourced from officials and valid documents, encompassing rules, scientific literature, publications, and trusted news outlets. The study encompasses the following data which are:

1. Official documents
   - 1.1 Convention on the Elimination of All Forms of Discrimination against Women (CEDAW);
   - 1.2 Universal Declaration of Human Rights (UDHR);
   - 1.3 FAO Gender and Agriculture Reports;
   - 1.4 SDGs Framework (khususnya SDGs 2);
   - 1.5 Laporan ASEAN tentang gender, rural women, dan digital agriculture;
2. Academic literatures and reputable news outlets pertinent to the evolution of women's participation in smart agriculture in Southeast Asia.

2.3. Data Acquisition Methods

The data acquisition methods employed in qualitative analysis encompass a minimum of five systematic stages to guarantee the validity, relevance, and depth of analysis of the process and its outcomes. If the researcher employs the READ method within the research design, the data

collection techniques presented here constitute a further elaboration of that methodology, as detailed below:

1. Identification and Selection of Documents: Analogous to the research design, documents are chosen and identified to ascertain which categories are pertinent to the research focus and objectives;
2. Document Collection: Methodically recording the origins and attributes of the documents;
3. Document Evaluation and Selection: Documents are chosen from a timeframe of up to 5-10 years prior and encompass both empirical and systematic data pertaining to gender, agriculture, and wise farming for women in Southeast Asia. The documents are subsequently reviewed and chosen based on their compliance with academic standards;
4. Data Extraction: Conducting a comprehensive review of the documents and systematically extracting pertinent data. This study encompasses the extracted data on participation rates and Southeast Asian women's programs in smart farming, national policies pertaining to women's roles in smart farming, obstacles encountered by women in accessing smart farming, and the implementation of international law to enhance the role of Southeast Asian women in smart farming.
5. Analysis and Interpretation: Conducting data analysis and synthesizing findings across documents to strengthen the validity of the research

(Daruhadi & Sopiati, 2024)

2.3. Methods of Data Analysis

Thematic content analysis is a prevalent analytical method in quantitative research for identifying, analyzing, and elucidating patterns within data. The approach is adaptable and can be derived from diverse data sources, including interviews, documents, and observations. The phases of thematic content analysis are delineated as follows (Naeem et al., 2023):

1. Data Familiarization: Conducting a comprehensive review and gaining an in-depth comprehension of the data;
2. Coding: Categorizing data, including the application of smart farming in Southeast Asia and the influence of international law;
3. Theme Identification: Integrating themes into research findings, such as gender inequality in smart farming and inadequate implementation of international law;
4. Contextual Interpretation: Presenting the research findings within a coherent and structured narrative.

3. Results and Discussions

3.1 Women Participation in Southeast Asia Smart Farming Process

Socio-cultural norms, limited land ownership, lack of access to credit, and insufficient training opportunities disproportionately exclude women from the benefits of smart farming in Southeast Asia (Sundram, 2023b). However, it was discovered through research that there are indeed activities that fall under the category of women in smart farming participations. The findings of the investigation from official reports and valid news articles are connected to women's involvement in smart agricultural empowerment in Southeast Asia. Moreover, the findings are shown below.

1. Brunei Darussalam

Brunei Darussalam highlighted the adoption of digital technology and IoT to attract young people to the agricultural sector. Initiatives like S&R Aquafarm demonstrate that smart farming in Brunei is open to the participation of all groups, including women, especially in the context of entrepreneurship and urban farming (Musa et al., 2022).

2. Cambodia

Women's participation in forest and fisheries management groups can lead to better resource governance and conservation outcomes. For example, the *Women Farmer Champions* platform in Cambodia allows women to join and voice environmental concerns to the government (OECD and ASEAN Secretariat, 2021a).

3. Indonesia

The *Agri-Fin Mobile* digital platform provides integrated agricultural, market, and financial services, enabling women farmers to access market information and financial services via mobile phones. Microfinance institutions like KOMIDA or Koperasi Mitra Dhuafa (Mitra Dhuafa Cooperative) provide credit, financial training, and healthcare services to women farmers (OECD and ASEAN Secretariat, 2021a).

4. Lao PDR

In 2021, Lao PDR became the Southeast Asian country with the highest percentage of women working in the agricultural sector, estimated to be a total of 70% (ASEAN, 2021). Therefore, women's position is essential within the agricultural sector. The Power-to-the-Poor initiative in Lao PDR seeks to enhance household electricity access, with a particular focus on impoverished families and female-headed households. The program additionally offers interest-free financing to cover the costs of electricity connections for households headed by women. Research evidence indicates that national electricity access in Lao PDR experienced a rapid increase from 16% in 1995 to over 90% in 2017, following efforts to promote electricity access, thereby enabling greater participation in productive activities, including agriculture (Esmap, 2018).

5. Malaysia

In Malaysia, they launched Bayu Harvest application. The Bayu Harvest application

exemplifies agricultural digitalization by linking female producers in Sabah with urban markets. Digital platforms additionally offer real-time market price data, enabling producers to make more informed sales decisions (Patil et al., 2025). This is the function of the smart agricultural feature of Bayu Harvest. This application eliminates reliance on intermediaries, enabling female producers to sell their products directly to consumers, thereby securing more equitable prices and increased profit margins. Female farmers have the ability to submit product profiles, oversee inventory, and sell directly to consumers, thereby enhancing their standing within the supply chain and boosting their earnings. (OECD and ASEAN Secretariat, 2021a).

6. Myanmar

Women in Myanmar contribute a significant proportion to agriculture: according to the study "Women and youth in Myanmar agriculture," women in farming households perform 39% of household agricultural workdays, and 43% of wage laborers in the agricultural sector are women (Lambrecht et al., 2021).

The Climate-Smart Agriculture (CSA) initiative in Myanmar also considers the gender dimension such as "Integrating gender dimensions in the Myanmar climate-smart villages (CSV)" states that the CSA program in Myanmar gives "special attention to studying and responding to the needs of women in smallholder agriculture."(Maria Helen Dayo et al., 2021).

7. Philippines

Research conducted in the Philippines indicates that women play a highly active role in the production, post-harvest processing, marketing, and training of new members in seaweed cultivation (Ramirez et al., 2020). At the Quinluban Island Agutaya Fisherfolk Marketing Cooperative, 84% of the members are women. They manage the store, oversee marketing, and train other members in seaweed production and sales (OECD and ASEAN Secretariat, 2021a). Despite substantial participation, women continue to encounter obstacles including the gender wage disparity, restricted access to land ownership, and male dominance in leadership roles (Mengo et al., 2023). Nevertheless, in the context of smart farming, women's involvement in production becomes prevalent as their roles establish commercial networks and educational instruction through digital technology.

8. Singapore

Singapore is an industrial country with limited territory available for the implementation of smart farming. Nevertheless, when examining the agri-foodtech sector in Singapore, accelerator programs highlight women as founders. For example, in the *Better Earth Ventures: Women Founders & Funders Singapore 2025 program*, it is stated that "nearly half of the selected ventures are co-founded by women" in the agritech sector (Better Earth Ventures, 2025).

9. Thailand

Similar with numerous other Southeast Asian countries, Thailand is harnessing digital technology to enhance women's engagement in wise farming. CCDKM (*Centre of Communication and Development Knowledge Management*) trained over 50,000 young girls and women in the use of ICT for "smart agriculture"; they operated smart irrigation systems, drones, and marketing applications, and volunteered to transfer knowledge to villages (OECD and ASEAN Secretariat, 2021a).

10. Vietnam

Vietnamese smallholder farmers, including women, increasingly use the internet, mobile applications, and digital platforms to address production and marketing challenges. The National Women-led Business Start-up (NWBSP) program in Vietnam supports women in developing agribusinesses, emphasizing the adoption of digital technologies for marketing and management. This aligns with broader national efforts to modernize agriculture and empower women entrepreneurs (OECD and ASEAN Secretariat, 2021b). E-commerce and digital marketing allow women-led agribusinesses to reach broader markets, reduce costs, and improve competitiveness. Success stories, such as VinEco, demonstrate how digital integration can transform agricultural sales and management (Trang et al., 2024).

11. Timor Leste / East Timor

As the newest ASEAN member and most recent country in Southeast Asia, women farmers in East Timor often face challenges accessing modern agricultural tools, irrigation systems, and training on new technologies due to socio-cultural norms and lower literacy rates (Nalle et al., 2025). Households with higher female labor participation are more likely to adopt improved crop varieties and engage in market activities, especially in petty trading, which is often managed by women. In order to that situation, community-based seed multiplication, can significantly improve women’s access to agricultural extension and training, leading to more diverse cropping practices in East Timor while also increasing women participation in smart farming activities.

3.2 International Law Framework for Strengthening Southeast Asian Women Paticipation in Smart Farming Process

Based on the presented findings, they have solid arguments that application of smart farming in Southeast Asia has good potential to enhance agricultural productivity, improve food safety, reduce environmental impact, and support the achievement of SDG 2 (zero hunger) by promoting sustainable food systems and optimizing resource use. While ASEAN countries have recognized the importance of gender equality in agriculture, the implementation of gender-sensitive policies remains insufficient. International frameworks like CEDAW and FAO guidelines are referenced in national strategies, but practical enforcement and monitoring are lacking. All of this is attributable to

the characteristics of international law. The *FAO Guidelines* are non-binding. Nonetheless, Southeast Asian nations may utilize CEDAW and ICESCR to bolster women's participation in smart farming and ensure access in alignment with these international statutes. Almost all countries in Southeast Asian region have ratified CEDAW and ICESCR. Consequently, the issue lies not in the failure to enact and accept a regulation within its nation. But also how far these international legal instruments facilitate capacity-building and inclusive policy design to address the gender gap in this region. International frameworks such as CEDAW and ICESCR frequently neglect the diversity of gender systems and the particular needs of women in various countries or communities. Cultural, societal, and economic obstacles continue to restrict women's access to agricultural technology and smart farming, notwithstanding formal legal safeguards (Rola-Rubzen et al., 2020). Monitoring and enforcement of CEDAW and ICESCR at the national level remain inadequate, resulting in the insufficient protection of women's rights in smart farming (Veneracion-Rallonza, 2018).

Table 1. Acquisition parameters in the field

Instrument	Focus on Women's Protection	Status
CEDAW	Access to land, credit, and training	Binding
ICESCR	Right to non-discriminatory food access	Binding
FAO Guidelines	Gender inclusivity in the food system	Non-Binding

4. CONCLUSIONS

This study concludes that the gender gap in the adoption of smart farming in Southeast Asia continues to pose a considerable challenge, despite women's substantial contributions to food security and agricultural development. Based on analysis of international documents, ASEAN reports, and various studies, it has been determined that women continue to encounter restricted access to modern agricultural technology, training, land tenure, and technical information, which are essential for implementing smart farming. Socio-cultural barriers, unequal distribution of domestic responsibilities, and economic constraints exacerbate these inequalities.

Furthermore, international legal frameworks such as CEDAW and ICESCR can effectively enhance the protection of women's access to agricultural technology and resources. However, its implementation at the national level remains suboptimal. ASEAN countries tend to have adopted regulations supporting gender equality. However, these measures are often not complemented by robust monitoring and enforcement mechanisms. In certain countries, smart agricultural initiatives have started to include women, but unfortunatelly, their implementation remains inconsistent and lacks a comprehensive approach.

Therefore, although smart farming possesses the potential to enhance productivity, resource efficiency, and food security, these advantages are not yet uniformly accessible to women. Without the implementation of inclusive policy measures, it is anticipated that gender disparities will persist and potentially widen as agricultural digitalization advances in Southeast Asia.

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