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Collaborative Networks of the Agribusiness and Technology Park of IPB University Based on Farmer Communities within a Welfare-Oriented Digital Ecosystem

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ABSTRACT

This study identifies how Agribusiness and Technology Park of IPB University (ATP IPB)*, a technology park entity at a state university, builds collaborative networks based on farmer communities within a welfare-oriented digital ecosystem. This study aims to describe the role of digital technology in the Industrial Revolution 4.0 era that supports ATP IPB in expanding collaborative networks, especially with farmer communities and markets using the internet. This study explains how the WhatsApp digital application and website-based information systems or mobile applications are used to build collaborative networks between ATP IPB, farmer communities and markets. With qualitative analysis, this study reveals that ATP IPB functions as a link between farmer communities to modern markets, both supermarkets and aggrotech start-ups that also utilize digital technology to access consumers. The results of the study show that the process of interaction, communication and coordination between ATP IPB, farmer communities, and consumers supported using the internet and digital technology such as WhatsApp applications, websites, e-mail, and e-commerce becomes more efficient. This study concludes that the penetration of internet and digital technology strengthens the collaborative networks between ATP IPB based on farmer communities in a welfare-oriented digital ecosystem.*

Keywords: collaboration, digital technology, farmer communities, internet, networking

INTRODUCTION

Collaborative networks established in the agricultural sector can improve the welfare of those involved in them. These collaborative networks involve various stakeholders such as farmer communities, universities, government institutions, and the private sector in achieving food security and sustaining community livelihoods. Through such networks, universities can boost agricultural productivity, including by assisting farmers through technology and social innovation within a digital ecosystem. This context aligns with the findings of Li et al. (2023) from their research on National Agricultural Science and Technology Parks (NASTPs) in China, which show that increased entrepreneurial support and strengthened demonstration and promotion programs can enhance innovation efficiency. Innovation efficiency refers to an organization's ability to utilize inputs land, capital, research, and service facilities to generate innovation outputs such as economic value, patents, and technology adoption. Key factors such as leading enterprises, income levels, and innovation support positively correlate with innovation efficiency. Moreover, effective demonstration activities increase farmers' adoption of new technologies, raise productivity and income, and improve welfare in the agricultural sector.

Before discussing technology and collaboration further, the meaning of agriculture as a primary economic sector must also be elaborated. Agriculture itself refers to human activities aimed at producing food and fiber through the intentional and controlled cultivation of plants and animals (Spedding, 1988). Agriculture is the most crucial sector for food production. Based on data from Statistics Indonesia (BPS), the agricultural category contributed significantly 12.53% to Indonesia's Gross Domestic Product (GDP) at current prices in 2023, representing an increase of 0.13% from the previous year (BPS, 2024). Therefore, it is undeniable that Indonesia's economic and demographic structure remains dominated by a rural economy based on agromaritime livelihoods (Satria, 2021).

These dynamics become more complex when linked to global and national population growth. The United Nations projects that the world population will increase to around 8.5 billion by 2030 and reach 9.7 billion by 2050 (UN DESA, 2022). By 2100, the global population is expected to be between 8.9 and 12.4 billion. Data released by the United Nations Development Programme (UNDP, 2021), show that in developing countries, 90% of the population consists of smallholder farmers. Meanwhile, as one of the developing countries in Southeast Asia, Indonesia has experienced significant population growth, with a population of 284.4 million (BPS, 2025). These data highlight that population issues both globally and nationally cannot be underestimated, since every human requires food sourced from agricultural activities.

This condition underscores the crucial role of agriculture in addressing malnutrition and poverty. The Food and Agriculture Organization (FAO, 2017) estimates that 815 million people worldwide experience chronic undernourishment, mostly in low and lower-middle-income countries. This phenomenon occurs partly due to the absence of structural economic transformation among these populations. FAO further predicts that around 1.75 billion people live on less than USD 3.10 per day (FAO, 2017). Amidst these structural challenges, new disruptions have emerged with the advent of the Fourth Industrial Revolution (Industry 4.0), which also affects the food sector. Consequently, the discourse on Agriculture 4.0 has gained prominence. Agriculture 4.0 involves the use of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, blockchain, drones, and robotics. This approach enables precise, high-value, efficient, and sustainable agricultural production (Satria, 2021).

Amid these challenges, digital technologies bring new opportunities for the agricultural sector. However, digital technologies do not guarantee that farmer communities can fully get benefits from them. Many farmers, particularly those with limited formal education, struggle to use digital technologies effectively. In some countries, agricultural land fragmentation further weakens farmers' capacity to adopt new technologies (FAO, 2019) resulting in low bargaining power to access digital ecosystems.

Nevertheless, digital technology holds considerable potential for agriculture. Internet-based technologies create opportunities for Indonesian farmers to build new social formations within digital ecosystems. Within these ecosystems, significant shifts occur in farmers' interactions, relationships, and networks with markets. Rural farmer communities can leverage internet interventions, local resources, and local values as social and digital technologies in managing their business processes. Social innovation can encourage collaborative governance systems that foster multi-stakeholder cooperation, particularly in business development and rural economic empowerment. To realize such innovations, creativity is necessary so that new economic opportunities including product creation can emerge (Kolopaking, et al., 2022)

Furthermore, digital technologies have influenced agricultural marketing concepts and disrupted business chains. These concepts align with the principles of Agriculture 4.0, characterized by digital technology use and digitally literate consumers. In digital marketing, smartphone-based applications or platforms serve as essential tools. Consumers can access and purchase products displayed on these applications (Satria, 2021). The disruption era has also led to a growing number of agricultural start-ups or marketplaces in Indonesia that facilitate easy-to-access platforms through smartphones.

Marketing is defined as an activity focused on managing and engaging profitable customer relationships (Kotler & Armstrong, 2018). With the emergence of Industry 4.0, the concept of digital marketing also referred to as marketing 4.0 has evolved. Kotler et al. (2017) describe marketing 4.0 as a marketing approach that integrates online and offline interactions between companies and customers. Digital marketing does not eliminate traditional marketing; instead, the two coexist, aligning closely with the concept of digital agriculture.

Within this context of digital technology development, this study focuses on the expanding collaborative networks in agriculture, particularly through interdisciplinary approaches that integrate rural sociology, digital sociology, collaboration studies, and social innovation. Nashiruddin (2017), emphasizes that commercializing research-based technologies requires network development. Previous studies often analyze farmer communities through the lens of local culture and agrarian systems. However, in the disruption era, farmer community activities such as production, distribution, and social relations are profoundly influenced by digital transformation.

Based on this background, the main research question of this study is: How does the Agribusiness and Technology Park of IPB University (ATP IPB) develop a collaborative network based on farmer communities within a digital ecosystem? The study also aims to identify ATP IPB activities that contribute to building farmer community based collaborative networks within a welfare-oriented digital ecosystem. In line with these objectives, the study adopts a guiding hypothesis: Internet penetration enhances ATP IPB's ability to build and strengthen collaborative networks based on farmer communities within a welfare-oriented digital ecosystem.

As an analytical framework, this study utilizes Castells' (2009) grand theory of the *network society* to understand digital technology based social structures. According to Castells, social structures evolved with the advent of the internet, which created a new social structure known as the network society—a global system shaping the characteristics of contemporary globalization.

Castells' concept of network society is referenced by Prof. Dr. S. M. P. Tjondronegoro, a pioneer of rural sociology studies in Indonesia. According to Tjondronegoro, technology drives societal transformation. The network society concept resonates with the idea of the "Global Village," in which information and communication technologies serve as connectivity tools and social bridges within Indonesia's national context (Kolopaking et al., 2021).

This study also employs the middle-range theory of collaboration by Wood & Gray (1991) to analyze relational dynamics among actors within networks. Collaboration, according to Wood and Gray, requires interaction and relationships through which stakeholders meet and work together toward shared goals. They define collaboration as a condition in which stakeholders engage in a process guided by shared rules, norms, and structures. Thus, collaborative networks can be understood as equal relationships built through interactions aimed at solving problems while adhering to existing norms, rules, and structures.

METHODS

To address the research question, this study employed a qualitative research method. The qualitative paradigm is rooted in the tradition of naturalistic phenomenology (Silalahi, 2015). Van Manen (2016) states that phenomenology, as a method, illustrates how individuals focus their attention on lived experiences, how they perceive and understand the world in which they live as human beings. Qualitative research emphasizes how individuals interpret and describe complex conditions (Creswell, 2015).

This study was conducted over eight months, from December 2023 to July 2024. The researcher conducted fieldwork by visiting locations where the informants were situated. Data collection took place in farmers' fields and at the Agribusiness and Technology Park of IPB University (ATP IPB) in Bogor Regency.

The research began with the identification of key informants, the individuals considered authoritative and reliable in providing essential information to trace the research object (Spradley (1980) in Sugiyono, 2022). In this study, the key informants consisted of ATP IPB management or the management of the Directorate for Agromaritime Community Development (DPMA), farmer community members who partner with ATP IPB, and market offtaker management.

The researcher used both primary and secondary data. In qualitative research, data are obtained from multiple sources through triangulation and collected continuously until reaching saturation. Triangulation was applied through various data collection techniques, including participant observation and in-depth interviews for primary data, and documentation studies for secondary data, conducted concurrently with the same data sources (Sugiyono, 2022).

Data processing was carried out by simplifying and presenting the information obtained. In qualitative research, data analysis begins when the researcher formulates and clarifies the research problem even before entering the field and continues throughout the data collection process until research findings emerge (Nasution, 1988 in Sugiyono, 2022).

The researcher analyzed the farmers' income levels and the sustainability of ATP IPB's collaborative network based on farmer communities within a welfare-oriented digital ecosystem enabled through internet and digital technology use. The researcher then interpreted the data and provided theoretical meaning to the results of the analysis.

RESULTS AND DISCUSSION

General Overview and Transformation of ATP IPB

The lives of farmers continue to change as the agricultural sector faces global and local dynamics. These changes arise from small interactions among farmers that eventually form larger interactions across space and time, both in rural and urban settings. Such spaces become meeting points for farmer communities, knowledge systems, and new value systems. These meeting points can be understood as hubs, the nodes that connect one actor to another. The Agribusiness and Technology Park of IPB University (ATP IPB), as an innovation showcase area, functions as such a hub within the collaborative networks it has developed since its establishment.

ATP IPB also acts as a bridge over structural holes (Burt, 1992) linking farmer communities with markets that depend on each other to create supply and value chains within a digital ecosystem. These networks emerge because ATP IPB connects two previously unlinked contacts or actors. According to Burt (1992), structural holes are gaps or discontinuities in social structures where nonredundant contacts exist, enabling an intermediary actor to serve as a broker.

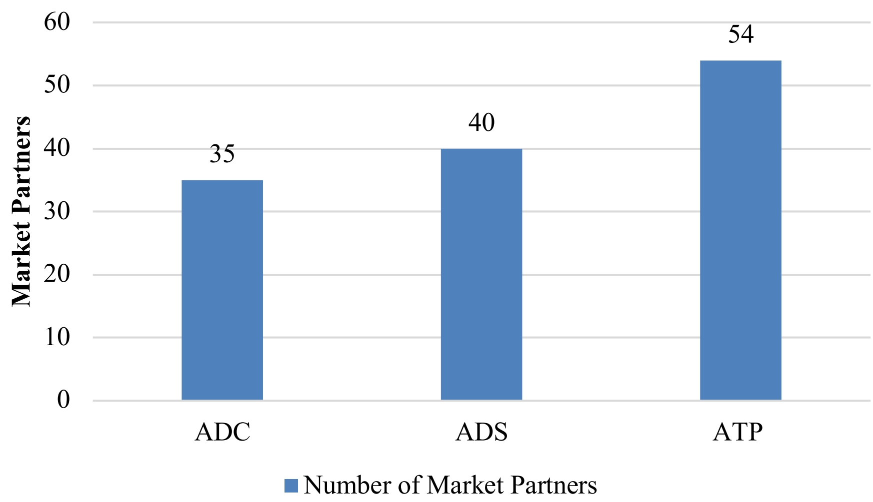

Figure 1. Number of Market Partners Based on the Management Unit Period. Source: ATP IPB 2025 data, Syafaaty 2015, Wismawati 2017, processed by the author (2025)

As of 2025, ATP IPB operates under the Directorate for Agromaritime Community Development of IPB University (DPMA, 2025). In the evolving landscape of modern agriculture, ATP IPB does not merely conduct production or demonstration plot activities. It has the mandate to provide services and community engagement, particularly for agricultural communities. ATP IPB was established to improve farmers' incomes, including smallholders living near the university. Embracing the slogan "Connecting Farmers to Modern Supermarkets," ATP IPB facilitates the flow of technology, innovation, and agricultural products from farmer communities to consumers through collaborative networks that also involve wider markets. ATP IPB's 54 market partners include large retailers and agritech start-ups such as GrandLucky, Yogya, Superindo, Indomaret, Total Buah Segar, Sayurbox, Kecipir, and IDBotani. Developments in market partnerships are shown in Figure 1.

ATP IPB manages 4.37 hectares of organic land and 55.97 hectares of conventional agricultural land with a total of 759 partner farmers. These lands are located in Cikarawang Village, Dramaga Subdistrict, Bogor Regency; in Pasir Sarongge; Kebun Jeruk; Ciputri Village, Pacet Subdistrict, Cianjur Regency; and in other farmer-managed locations. With this production capacity, ATP IPB is able to meet diverse market demands for both organic and conventional agricultural products. Furthermore, ATP IPB has become an iconic destination for visitors to IPB University, serving as an agro-edutourism site at the Cikarawang Farm (DPMA IPB, personal communication, August 4, 2025). ATP IPB's institutional transformation is shown in Figure 2.

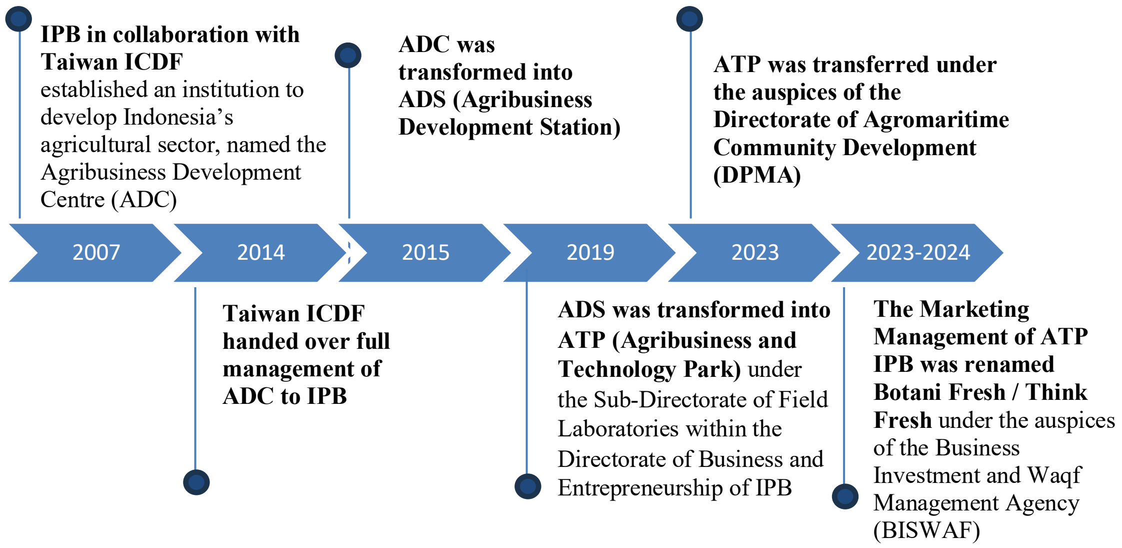

Figure 2. The Development Pathway of ATP IPB. Source: ATP IPB data, processed by the author (2025)

ATP IPB as a Science and Technology Park

Understanding ATP IPB requires examining it within the framework of a Science and Technology Park (STP). The International Association of Science Parks (IASP) explains that the terms *science park*, *technology park*, *research park*, and *technopole* are interchangeable (IASP, 2024). An STP is defined as an organization managed by specialized professionals with the mission of enhancing community welfare by fostering a culture of innovation and competitiveness among knowledge-based institutions and businesses.

United Nations Industrial Development Organization (UNIDO, 2021) together with United Nations Conference on Trade and Development (UNCTAD) and The World Bank defines an STP as an area that supports technological development through research activities and by engaging technology-based companies to generate innovation and knowledge-driven economic development, supported by an enabling ecosystem for research and development (R&D).

Li et al. (2023) explain that China, known for its strong economic development agenda, has implemented a strategy to modernize agriculture not only through increased production quantity but also by prioritizing quality. National Agricultural Science and Technology Parks (NASTPs) serve key roles in integrating science and technology to advance rural agriculture. NASTPs link farmers, companies, and markets, serving as facilitators of innovation and transformation in the agricultural sector.

As an STP within a public university, ATP IPB's role in Indonesia's agricultural transformation is highly relevant. Its function as a structural hole bridge that connects farmer communities to wider markets, similar to the function of NASTPs in China which provides valuable insights for policymakers involved in agricultural development.

Farmer Communities as ATP IPB's Producer Network

Institutional changes within IPB University have influenced the number of ATP IPB's partner farmers. When ATP was still the Agribusiness Development Center (ADC), the number of partner farmers reached 413. When the institution transitioned into the Agribusiness Development Station (ADS), the number decreased to 58 farmers (Syafaaty, 2015). After becoming ATP IPB, the number increased significantly to 759 farmers in 2025 (DPMA IPB, 2025). This number fluctuates depending on partnership dynamics.

The following graph shows the number of partner farmers based on the management unit period (Figure 3). Meanwhile, the data on the development of the number of ATP IPB partner farmers in 2021, 2022, 2023, and 2025 is presented in Figure 4.

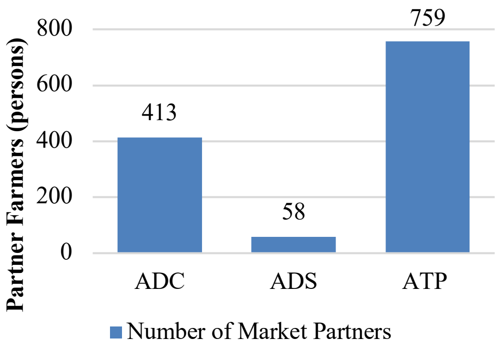

Figure 3. Number of Partner Farmers by Management Unit Period. Source: ATP IPB data, Syafaaty (2015), Wismawati (2017) processed by the author (2025)

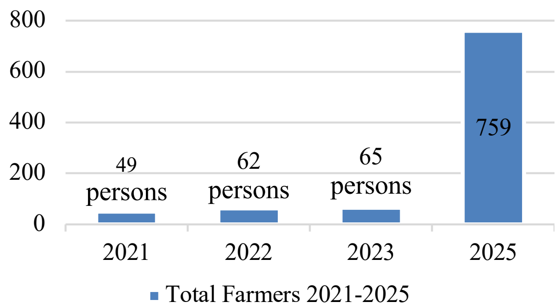

Figure 4. Development of the Number of ATP IPB Partner Farmers. Source: ATP IPB data, processed by the author (2025)

Based on data obtained from ATP IPB in 2025, the number of partner farmers collaborating with ATP IPB has increased over the past three years. Since 2021, the number of partner farmers supplying agricultural products to ATP IPB was 49 individuals. In 2022, this number increased to 62 farmers. In 2023, the number of partner farmers continued to rise, although not significantly, reaching 65 individuals. After ATP IPB came under the coordination of DPMA, numerous programs were implemented, resulting in a substantial increase in the number of partner farmers, reaching 759 individuals from various regions. The number of ATP IPB partner farmers by commodity in 2025 is presented as follows:

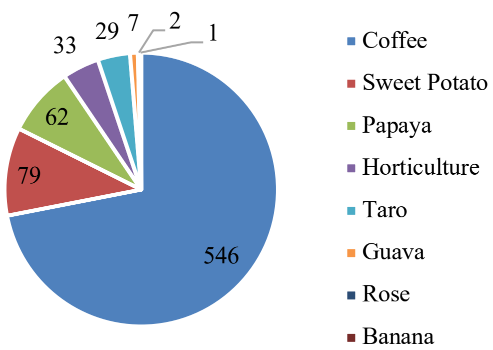

Figure 5. Number of ATP IPB Partner Farmers by Commodity in 2025.
Source: ATP IPB data, processed by the author (2025)

The data in Figure 5 show the distribution of ATP IPB partner farmers by commodity in 2025, totaling 759 farmers. The largest group consists of coffee farmers, with 546 partner farmers. This reflects ATP IPB's focus under DPMA on developing the plantation sector, which has substantial market potential both domestically and for export. The second-largest group is horticultural farmers, totaling 79 partner farmers. The third-largest group consists of tuber farmers, with 62 farmers; followed by taro farmers, with 33 partner farmers; and guava farmers, with 29 partner farmers. Additionally, there are 2 rose farmers and 1 banana farmer partnering with ATP IPB.

ATP IPB, together with farmer communities, continues to explore ways to produce a substantial and diverse range of agricultural products, including leafy vegetables, fruit vegetables, stem vegetables, flower vegetables, tubers, coffee, and other agricultural products demanded by the market. These activities are supported by the use of digital technologies, especially for building interaction, communication, and reaching wider consumer segments. Among the many agricultural product varieties, seven types particularly organic vegetables were the most widely produced in 2021, 2022, and 2023. This is supported by vegetable production records that demonstrate increasing or fluctuating trends as shown in Table 1 and Table 2.

Tabel 1. Vegetable Production Volume of ATP IPB

No	Product Name	2021 (kg)	2022 (kg)	2023 (kg)	Grand Total (kg)
1	Green Spinach	5,853.9	5,729.15	5,849.1	17,432.15
2	Water Spinach	3,237.53	4,131.8	4,760.1	12,129.43
3	Pak Choi	3,285.5	4,213.2	3,671.35	11,170.05
4	Long Purple Eggplant	8,920.28	998.49	839.11	10,757.88
5	Choy Sum	2,857.25	3,299.15	2,584.45	8,740.85
6	Cherry Tomato	2,963.8	827.65	4,387.3	8,178.75
7	Chili Pepper		7,863.41	5.95	7,869.36

Source: ATP IPB data, processed by the author (2025)

Tabel 2. Revenue and Production of ATP IPB Partner Farmers, 2021–2023

Year	Revenue (IDR)	Vegetable Delivery (kg)
2021	609,777,725	58,273
2022	584,669,180	60,521
2023	603,894,230	47,092
Total	1,798,341,135	165,886
Average	599,447,045	58,273

Source: ATP IPB data, processed by the author (2025)

The total production of ATP IPB together with its partner farmers in 2021 generated partner farmer revenue amounting to IDR 609,777,725 with a total production volume of 58,273 kg. In 2022, partner farmer revenue decreased to IDR 584,669,180 with a total production of 60,521 kg. This decline did not last long, as in 2023 partner farmer revenue increased to IDR 603,894,230 with a production volume of 47,092 kg, indicating that farmers became more productive than in the previous year. In total, ATP IPB's purchases of agricultural products from its partner farmers amounted to IDR 1,798,341,135 with a total of 165,886 kg of agricultural products over the three-year period. When averaged, partner farmers earned IDR 599,449,045 per year with an average vegetable production volume of 58,273 kg over the past three years.

In addition to producing vegetables, in 2024–2025 ATP IPB and its partner farmers produced papaya using a variety developed by IPB academics, namely the Calina Papaya. This production further strengthened papaya's position as a flagship commodity within ATP IPB's collaborative network, contributing significantly to the institution's economic performance. This commodity has become both an identity marker and a key attraction for the market, as its quality and continuity of supply are maintained through structured coordination with farmer communities supported by internet and digital technologies.

The papaya production of ATP IPB's partner farmers in the 2024–2025 period reached 247,776 kg, or 247 tons, reinforcing its position as a flagship commodity. The scale of production reflects the capacity of partner farmer communities to consistently meet market demand, both for sales to market partners and for accessing export opportunities. The high production volume demonstrates the success of coordination between partner farmers and ATP IPB across the upstream–downstream chain, which includes planting schedules, supply management, and quality control. This coordination is effectively maintained through the use of the internet and digital technologies, particularly the use of WhatsApp by ATP IPB management, papaya-producing farmer communities, and market partners.

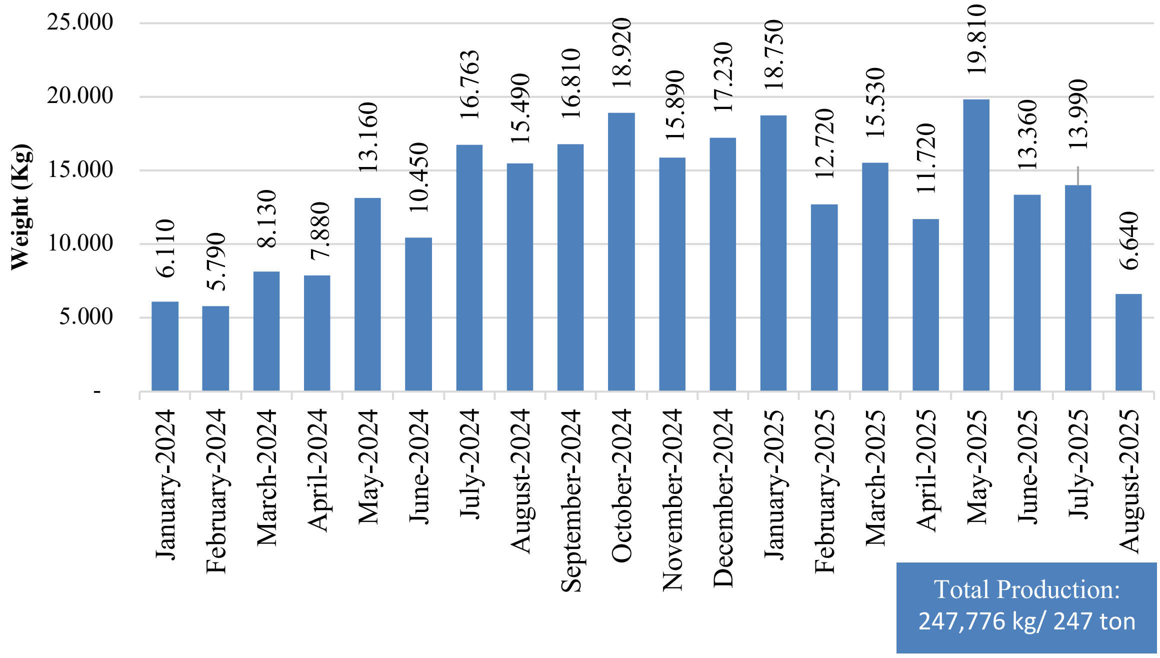

Figure 6. Production Volume of ATP IPB Partner Papaya Farmers, 2024–2025.
Source: ATP IPB data, processed by the author (2025)

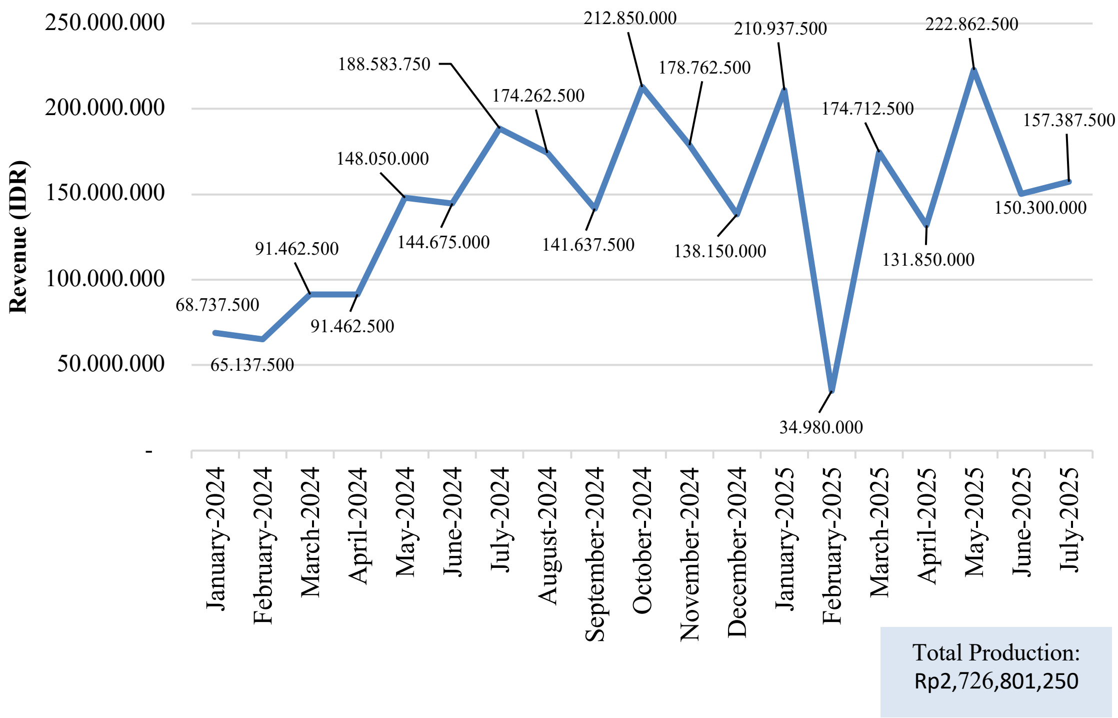

Figure 7. ATP IPB Revenue from Papaya Sales, 2024–2025.
Source: ATP IPB data, processed by the author (2025)

The revenue earned by ATP IPB from papaya sales in the 2024–2025 period amounted to IDR 2,726,801,250. This achievement reflects the substantial contribution of papaya as a flagship commodity within ATP IPB's collaborative network. The significant scale of this revenue demonstrates the success of both offline and digital marketing strategies implemented by all actors in the network, including ATP IPB management, papaya-producing farmer communities, and market partners particularly Indomaret.

In addition to fruit production, three ATP IPB partner farmers, specifically from Ciaruteun Village, Cibungbulang Subdistrict, Bogor Regency, produce organic vegetables such as spinach, water spinach, mustard greens, and others, which are supplied to supermarkets and online vegetable stores in Jakarta, Bogor, Depok, Tangerang, and Bekasi (Greater Jakarta). Their productivity records are as follows:

Tabel 3. Vegetable Production of Farmers in Ciaruteun Ilir, 2021–2023

Year	Production (kg)			Total Production (kg)
	Sukardi	Endang	Hidayat	
Annual Production				
2021	2,792.65	4,680.20	8,224.84	15,697.69
2022	3,160.10	4,232.95	7,122.17	14,515.22
2023	1,430.10	5,309.40	6,827.75	13,567.25
Total	**7,382.85**	**14,222.55**	**22,174.76**	**43,780.16**
Monthly Average				
2021	232.72	390.02	685.40	1,308.14
2022	263.34	352.75	593.52	1,209.61
2023	119.18	442.45	568.98	1,130.61
Total	**615.24**	**1,185.22**	**1,847.90**	**3,648.36**

The data show that the vegetable productivity of farmers from Ciaruteun Ilir Village such as Sukardi, Endang, and Hidayat experienced fluctuations from 2021 to 2023. Nevertheless, the available data indicate their strong production capacity, having produced 43 tons of vegetables over the three-year period. The farmers' monthly productivity also remained stable, reflecting consistent cultivation patterns.

Table 4. Revenue of Ciaruteun Ilir Farmers, 2021–2023

Year	Revenue (IDR)			Total Revenue (IDR)
	Sukardi	Endang	Hidayat	
Annual Production Volume				
2021	25,567,400	42,205,070	76,635,470	144,407,940
2022	26,120,450	37,855,550	63,380,300	127,356,300
2023	14,449,900	56,318,350	68,686,450	139,454,700
Total	**66,137,750**	**136,378,970**	**208,702,220**	**411,329,740**
Monthly Average				
2021	2,130,617	3,517,089	6,386,289	12,033,995
2022	2,176,704	3,154,629	5,281,692	10,613,025
2023	1,204,158	4,693,196	5,723,871	11,621,225
Total	**5,511,479**	**11,364,914**	**17,391,852**	**34,268,245**

The data in Table 4 show that the revenue of the three ATP IPB partner farmers from Ciaruteun Ilir Village remained relatively stable, despite fluctuations from year to year. Specifically, Sukardi's revenue experienced a decline in 2023. On the other hand, the revenue of Endang and Hidayat remained fairly stable. These data indicate that productive farming activities contribute significantly to the economic well-being of the community.

A study conducted by Normansyah et al. (2014) on the revenue analysis of vegetable farming in Ciaruteun Ilir Village, Cibungbulang Subdistrict, Bogor Regency, found that farmers spent around 26.8% of their revenue on cash expenses, including fertilizers, lime, vegetable ties, wages for hired labor, seeds, and irrigation. In addition, there were imputed costs amounting to 6.58% of income, which included the calculated rental value of self-owned land, family labor, equipment depreciation, and vegetables taken for household consumption. When combined, these cash and imputed costs constitute the total production cost or total farming expenditure, which accounted for 33% of income. After rounding, the total production cost for vegetable farming in Ciaruteun Ilir Village was 30%. This production cost proportion serves as a reference in the researcher's analysis to estimate the net income of ATP IPB partner farmers conducting their farming activities in Ciaruteun Ilir Village.

Table 5. Productivity and Welfare of Ciaruteun Ilir Farmers

Year	Average Monthly Income (IDR)	Production Costs[a]	Net Income[b]	Household Expenditure Needs[c]	Per Capita Expenditure Capacity [d]
Sukardi (5 family members)					
2021	2,130,617	639,185	1,491,432	2,092,190	298,286
2022	2,176,704	653,011	1,523,693	2,218,935	304,739
2023	1,204,158	361,247	842,911	2,410,870	168,582
Endang (3 family members)					
2021	3,517,089	1,055,127	2,461,962	1,255,314	820,654
2022	3,154,629	946,389	2,208,240	1,331,361	736,080
2023	4,693,196	1,407,959	3,285,237	1,446,522	1,095,079
Hidayat (2 family members)					
2021	6,386,289	1,915,887	4,470,402	836,876	2,235,201
2022	5,281,692	1,584,508	3,697,184	887,574	1,848,592
2023	5,723,871	1,717,161	4,006,710	964,348	2,003,355

a) 30% of income; b) income − production costs; c) number of household members × BPS Poverty Line Index; d) net income ÷ number of household members.

The productivity and income of the three partner farmers from Ciaruteun Ilir Village fluctuated from 2021 to 2023. Based on the data in Table 5, Sukardi's income over the three-year period (2021–2023), when compared with the BPS poverty line shown in Table 6, falls into the "non-prosperous" category, meaning that his income was insufficient to cover the monthly expenditure needs of all household members. Meanwhile, Haji Endang's income, when compared with the BPS poverty line, places him in the "prosperous" category, indicating that his income was sufficient to meet the household expenditure needs of all family members. Furthermore, Hidayat earned the highest income among the three, making him a "prosperous" farmer because his income was adequate to cover all household expenditure needs.

Table 6. Poverty Line of Bogor Regency According to the Central Statistics Agency (BPS)

Year	Poverty Line Index per Individual (IDR)
2021	418,438
2022	443,787
2023	482,174

Digital Technology in ATP IPB's Farmer Community Based Collaborative Network

In addition to production activities, the use of digital technology by ATP IPB is also evident in its daily operations. Digital technology has had a significant influence on ATP IPB's development in implementing a digital agriculture system. The concept of digital agriculture refers to a system capable of addressing challenges arising from climate change. Such a system is productive, adaptive, and anticipatory. Therefore, sustainability, profitability, and food security can be achieved through digital agriculture (Trendov et al., 2019).

Digital agriculture, climate-smart agriculture, and precision agriculture all require an appropriate ecosystem namely, a digital ecosystem. This digital ecosystem encompasses systems, stakeholders, and supportive environments that collectively empower communities in the use of digital technologies. The use of digital technology is also carried out to access services and open up economic opportunities (USAID, 2022). In this context, FAO (2022) presents its perspective on the digital ecosystem in rural areas, referring to it as the digital village ecosystem. According to FAO (2022), a digital village ecosystem is a form of digitalization created within the context of local economic, cultural, and environmental interests.

ATP IPB has entered the digital ecosystem by implementing digital technologies in both cultivation and marketing processes. ATP IPB has advanced into the era of Agriculture 4.0 through the use of various integrated digital technology applications, such as artificial intelligence (AI) and robotics. The application of internet-based digital technologies supports the automatic control of greenhouse temperature, humidity, light, and airflow based on data input into the system. In addition, automated seedling processes have also been implemented at ATP IPB (ATP IPB, personal interview, 13 December 2023). ATP IPB and its market partners use websites, e-mail, e-commerce platforms, and social media to market products produced together with partner farmers. The ATP IPB management, partner farmer communities, and market partners also make use of digital technologies, particularly the WhatsApp application, for digital communication and coordination. The development of communication technology use among each actor can be seen in Figure 8.

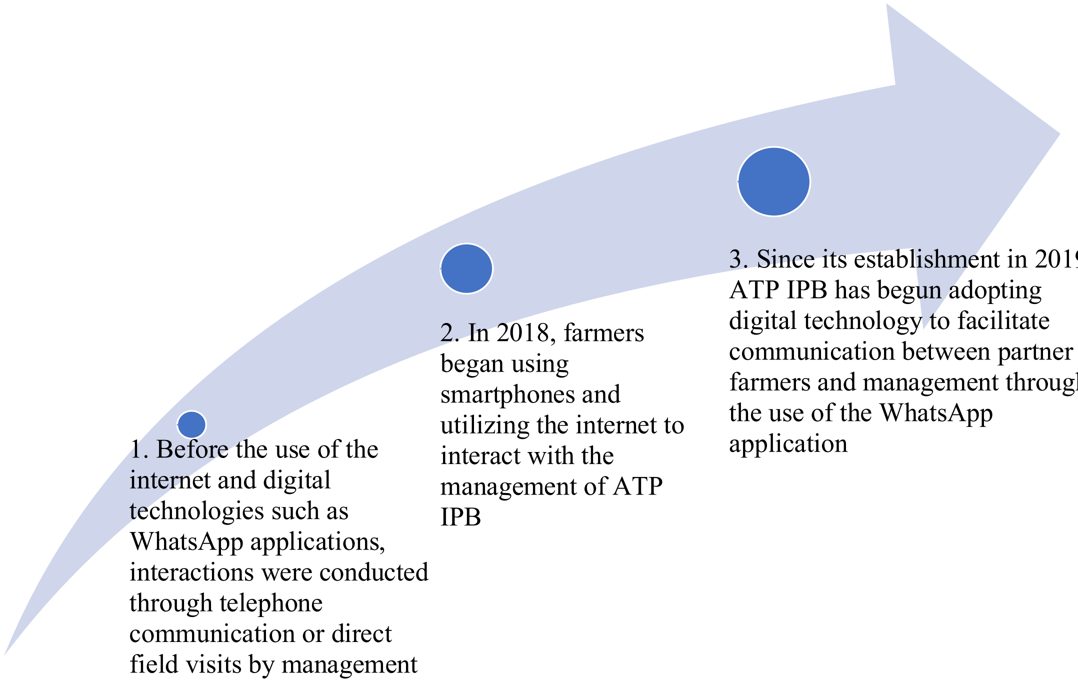

Figure 8. Development of Digital Technology Use in ATP IPB Agriculture

The shift in communication methods is clearly reflected in the use of WhatsApp, which has replaced older communication patterns based on phone calls and SMS among ATP IPB management, farmer communities, and market partners. ATP IPB's partner farmers particularly the three members from Ciaruteun Ilir Village, namely Sukardi, Endang, and Hidayat also use the WhatsApp application. These farmers are able to use WhatsApp because internet access is available in their village environment. This digital ecosystem enables farmers to engage in interaction and communication with ATP IPB management digitally.

Through WhatsApp, farmers can send written messages, photos, and videos showing the condition of their fields and vegetable crops directly to ATP IPB management. As a result, ATP IPB management can obtain updated information regarding the cultivation processes carried out by partner farmers. When facing problems, partner farmers can consult directly with ATP IPB management, particularly regarding pest control and technical aspects of organic farming.

In contrast to Sukardi, the other two partner farmers from Ciaruteun Ilir Village Haji Endang and Hidayat have a more limited understanding of the internet and digital technologies. Although both possess smartphones, they rarely bring them while working in the fields. Nevertheless, with smartphones and internet access, Haji Endang and Hidayat are still able to interact and communicate digitally with ATP IPB management through WhatsApp. When communicating via WhatsApp, both farmers require assistance from their children to operate the application features on their smartphones.

The smartphone is used by partner farmers to ask ATP IPB management about vegetable delivery quotas, planting schedules, harvesting schedules, and other issues encountered in the field. Such communication is carried out by calling ATP IPB management directly using the WhatsApp application. For instance, Haji Endang receives information via WhatsApp regarding meeting agendas between the partner farmer community and ATP IPB management. In the early stages of joining this IPB business unit, both Haji Endang and Hidayat were only able to use mobile phones for phone calls and SMS.

Furthermore, the sector currently being developed by ATP IPB together with farmer communities is referred to by Panetto et al. (2020) as the agri-food industry, an industry related to agriculture and food.

According to them, the agri-food sector is complex and requires the critical role of technology in its operations and decision-making processes. The presence of digital technology has also received particular attention from Lupton (2020) who argues that people today are highly dependent on digital technological devices. According to Lupton, this condition reflects that people in the present era can be considered a digital society.

On the other hand, despite technological advancement, the digital divide continues to persist due to inequalities between urban and rural areas. Rural areas lack adequate access to digital technologies, placing them at a disadvantage compared to urban areas, which have abundant access to digital facilities (Lynn et al., 2022).

The emergence of the internet and digital technologies has created its own impact on the networks and social relations among farmer communities, ATP IPB, and market actors. The findings of this study reinforce Castells' (2009) concept of a new social structure namely, the network society which is formed through the internet that accelerates the flow of information and coordination among the actors within the network. For Castells, this network society emerges because networks permeate every dimension of existing social organizations and social practices. The illustration of the network society formed among ATP IPB, farmer communities, and market actors can be seen in Figure 9.

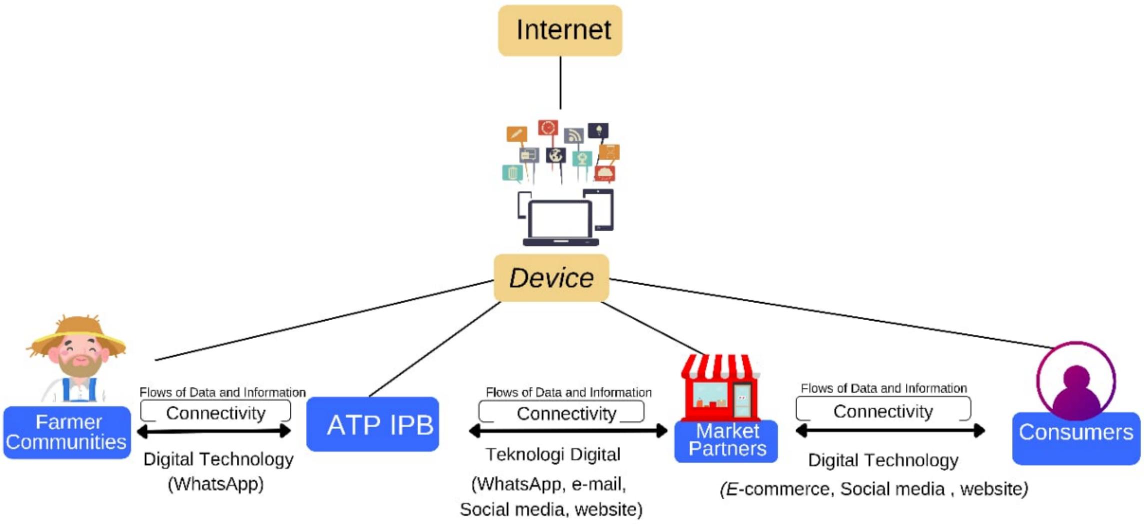

Figure 9. ATP IPB's Farmer Community–Based Collaborative Network within a Digital Ecosystem According to Manuel Castells' Network Society Theory (2010)

ATP IPB can also be regarded as a structural hole bridge that connects farmer communities with off-takers or consumer markets within the vegetable business chain. As a "player," borrowing Burt's terminology, ATP IPB occupies a strategic and highly influential role within the digital and agribusiness ecosystem, facilitating the smooth operation of the vegetable business for all parties involved. This collaborative network ultimately contributes to meeting consumer demand for agricultural products such as vegetables. ATP IPB acts as a technology facilitator as well as a bridge in Burt's (1992) structural hole theory serving as a connector between farmer communities and markets that were previously difficult to access, thereby opening new channels and strengthening digitally based collaborative networks. This can be seen in Figure 10.

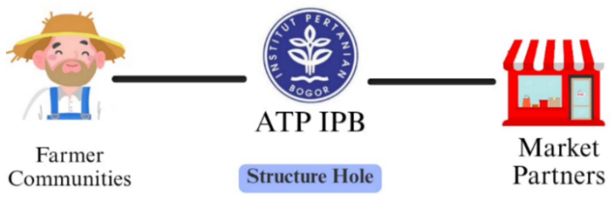

Figure 10. ATP IPB's Role as a Bridge that connects Farmers and Markets Based on Burt's (1992) Structural Hole Theory

If we observe the relationships within the network involving farmer communities, ATP IPB, and markets, what Wood & Gray (1991) describe becomes evident namely, that whenever a group of stakeholders interacts and works together to solve shared problems by applying rules, norms, and structures, collaboration can emerge among them. Each network formed around shared goals will naturally foster the development of collaborative relationships. This is made possible by the emergence of the internet and digital technologies that have penetrated rural areas and supported the collaborative networking processes being built.

This phenomenon aligns with Durugbo (2016) who developed the concept of collaborative networks in his study. Durugbo (2016) argues that collaborative networks evolve by utilizing information technology and socialization features to generate more competitive solutions and strengthen partnerships. These partnerships are driven by various factors such as business, supply chains, markets, and technological disruptions that exert pressure on companies operating independently. Collaborative networks determine operational approaches involving the sharing of risks, resources, responsibilities, and rewards. As Durugbo (2016), notes, through information technology, the goals of collaborative networks can be achieved. Furthermore, the social networks embedded within the collaborative networks among ATP IPB, farmer communities, and markets are also shaped by various considerations, including acquaintanceship, kinship, and friendship (Barnes, 1954).

CONCLUSION

The results of this study show that the penetration of the internet and digital technologies has facilitated ATP IPB in building and strengthening farmer community based collaborative networks within a digital ecosystem. The use of the internet and digital technologies by farmer communities, ATP IPB, market partners, and consumers through applications such as WhatsApp, e-mail, websites, e-commerce platforms, and others has made interaction and communication more effective and efficient. This condition reflects Castells' (2010) concept of the Network Society, in which internet-based connectivity supported by digital technologies becomes the main flow and infrastructure that connects actors in real time, particularly rural farmer communities and urban markets.

The internet and digital technologies enable online coordination and communication that reinforce collaborative networks and streamline the distribution of agricultural products from farmer communities to market partners, with ATP IPB acting as the intermediary. This position aligns with Burt's (1992) Structural Hole theory, whereby ATP IPB serves as a bridge spanning the structural gap between farmer communities and markets, enabling all actors to access information, control product flows, and gain added value.

The findings also show that digitalization through the utilization of the internet and digital technologies by farmer communities, ATP IPB, and market actors increases access and efficiency, which contributes to improved farmer incomes through optimized production and sales of agricultural products. Therefore, the use of the internet and digital technologies within this collaborative network supports the realization of a welfare-oriented digital ecosystem.

This study contributes novelty by integrating the theories of Castells, Wood & Gray, and Burt within the context of Indonesia's agribusiness digitalization. The study demonstrates ATP IPB's role as a digital connector that bridges farmer communities and markets through the use of the internet and digital technologies, thereby forming collaborative networks that enhance efficiency and improve farmer welfare.

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