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JOHN ALCANTARA FAJARDO

E-FARMING SYSTEM KNOWLEDGE TRANSFER: EXPLORING EXPERIENCES IN THE PHILIPPINES AND INDONESIA

Thesis Adviser:

ALEXANDER G. FLOR, PHD
Faculty of Information and Communication Studies

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E-FARMING SYSTEM KNOWLEDGE TRANSFER: EXPLORING EXPERIENCES IN THE PHILIPPINES AND INDONESIA

Acceptance Page

This paper prepared by **JOHN A. FAJARDO** with the title: **"E-FARMING SYSTEM KNOWLEDGE TRANSFER: EXPLORING EXPERIENCES IN THE PHILIPPINES AND INDONESIA"** is hereby accepted by the Faculty of Information and Communication Studies, U.P. Open University, in partial fulfillment of the requirements for the degree Doctor of Communication.

ALEXANDER G. FLOR, PHD
Chair, Dissertation Committee

____
(Date)

RIA MAE H. BORROMEO, Ph. D
Member, Dissertation Committee

____
(Date)

SERLIE B. JAMIAS, PHD
Member, Dissertation Committee

____
(Date)

DIEGO S. MARANAN, Ph.D
Dean
Faculty of Information and Communication Studies

30 September 2024
(Date)

Biographical Sketch

John A. Fajardo was born in agricultural farming community in Panganiban, Catanduanes with about 2,000 households. He is a passionate and seasoned scientist, leader, market development specialist, trainer, and coach in the food and agriculture industry in the Philippines and internationally for more than 20 years.

John finished his Masters' degree in Entomology, minor in Statistics from North Dakota State University, United States of America (USA) and BS in Agriculture major in Entomology from University of the Philippines Los Baños, Laguna, Philippines. He works with Bayer Crop Science and was recognized globally in 2021 with Distinguished Development Award, a prestigious honor given for his exemplary contributions. John had stints in Southeast Asia, Pakistan, India, China, Japan, Australia, Germany, Brazil, and USA as techno-commercial leader on strategy, people development, and product launches. He published several research papers, pesticide manual, and served as resource speakers in various organizations – Bayer Crop Science, DOLE Philippines, CropLife, and Philippine Rice Research Institute.

John served as President of the Pest Management Council of the Philippines (PMCP) and Philippine Association of Entomologists (PAE) during 2023-2024 and 2022-2023, respectively. These organizations underscore the value of pest management in food production, public health, and the environment. John is also fond of agricultural innovations and farming digitalization. He is a licensed pilot of Remotely Piloted Aerial System (drones) by the Civil Aviation Authority of the Philippines.

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Dedication

To my wife, Fritzie Cabrera Fajardo for the love and care, and who has been undeniably sympathetic not just during my DCOMM journey but for the entire escapades of the family.

To my children- Joana Daniella, John Yuxel, and Joana Frixie for being the catalysts of my strength especially during tough times in our lives, and who inspires me to continue learning and the quest for new knowledge.

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Abstract

Agriculture is complex and hermeneutic having epistemology in communications, innovations, politics, and society. This sector faces challenges in attaining food security due to climate change, low crop productivity and farm income, and aging farmer population. Traditional communication of crop advisories requires more time and has limited reach to farmers compared to digital communications. Although, the advances in digitalization also pose "last mile" challenges.

Complexity theory in communication offers pedagogy and practice in E-farming knowledge transfer to smallholder and marginalized farmers. The theory has been utilized in digital social advocacy, neo-diffusionism communication, management, and social science. This study aims to theorize Complexity theory in digital knowledge transfers in agriculture to drive social impact through effective utilization of crop advisories in digital media, mobile applications, and Internet of Things (IoT). Autoethnography, Focus Group Discussion, Key Informant Interviews, and User Acceptability Test qualitative research methods as well as desktop quantitative research were utilized in this study. One hundred (100) farmer respondents and ten (10) key informants were interviewed in the Philippines and Indonesia.

Results of the study showed that farmer motivations and needs are vital in digital crop advisory' success. The PCE (Planning-Communication-Evaluation) model is proposed leveraging Complexity theory. This model covers different interactions of adaptive agents in the social system including content developers, farmer personas, and other agents in the e-farming system. The social, digital adaptiveness, and muted voices of various farmer personas offer discourse to unravel and drive success in e-farming. The research findings also provide pragmatic and pedagogical implications of adaptive agents or nodes in digital farming advisories anchored from Complexity theory. Digital e-farming communication and the use of artificial intelligence (AI) offer a discourse in the production and adaptation of the sociality and reproduction of society through these agents interacting in a fluid or non-linear pattern.

Keywords: Complexity theory, Cybernetic tradition, E- Farming, Knowledge Transfer, Digital Crop Advisories, Digital Media, Social Media, Mobile Application in Agriculture, Internet of Things (IoT), Virtual Reality, Augmented Reality, Gamification, Artificial Intelligence

Chapter I

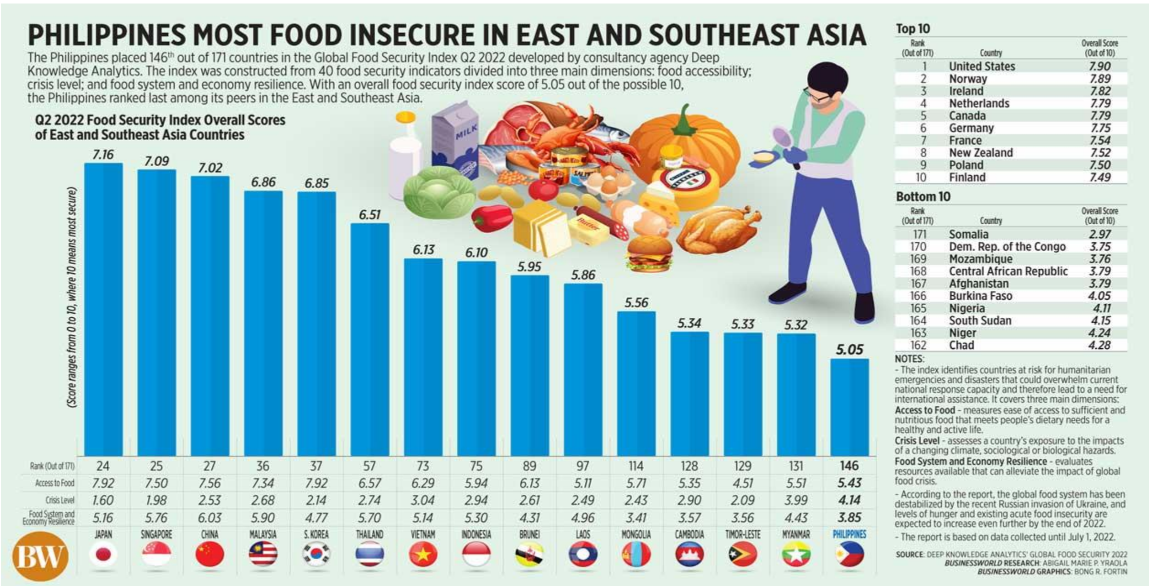
INTRODUCTION

Background of the Study

Food productivity and agricultural sustainability are vital to address the need of ballooning human population and the challenges of declining land and water resources. In 2022, the global population globally reached eight (8) billion already and is expected to increase up to about 9.7 billion by 2050 (United Nations, 2024).

The food security index of United States of America, Norway, Ireland, Netherlands, and Canada having digital and advanced farming technologies tops among 171 countries (Figure 1). Such index evaluates three key parameters to include access to food, crisis level, and food system and economy resilience. However, the food security rating is challenging in developing countries, especially in Southeast Asia. For instance, Philippines is considered one of the most food insecure country ranked at 146th although Indonesia is ranked better at 75th (Yraola, 2022).

Figure 1. *Food security index of different countries around the world during 2022.*



Millions of smallholder farmers in developing countries especially Philippines and Indonesia face many challenges throughout the farming journey. These include: 1) limited physical or digital access to agronomic solutions and information, 2) communication and information dissemination issues, 3) negative impact of climate change, 4) low farm income, and 5) aging farmer population (Sanchez Jr., 2015, Boersma et al., 2017, Cardama et al., 2021, Mastul et al., 2023, Mardiharini et al., 2023, Toumbourou et al., 2023, Bachtiar et al., 2024, and Le et al., 2024).

In the Philippines, the potential shortage of farmers in the next twelve years is one of the biggest societal concerns because of the aging farmer population, 57-years-old on average (Palis, 2020 and Lauengco, 2022). In Indonesia, the number of farmers decrease by 7.45% during the last decade from 31.7 million in 2013 into 29.3 million. Twenty two percent (22%) or about 6.2 million are millennial farmers with aged ranging from 19 to 39 years old (BPS Statistica, 2023) and only 12% are younger than 35 years old (Toumbourou et al., 2023). The youth perceived farming as a physically strenuous activity associated with a low income.

Parado Alvarez et al. (2018) studied the epistemological basis of agricultural education covering different facets in communication, training, politics, and the society. These include the agriculture-education-politics connections, pragmatic knowledge transfer, instruction-technology innovations-extension relatedness, sustainability projections, social movement participatory approach, reality transformations based on struggle of social equity and social justice, and agro-semiotic vision of training. The study underscores the implementation of training system covering various disciplines and transcends beyond the established programs in agriculture. It also highlighted that agrosemiotic approach can enhance education in agriculture.

The current farming systems and technologies need to improve and evolve to cope up with the increasing demand for nutritious, stable, and sustainable food. Furthermore, communication is another critical and equally important component of the whole farming ecosystem. Information, Communication, and Technologies (ICT) publications were prevalent in USA, China, and Brazil due to country's allocation of more resources to research, development, and agricultural productivity (Armenta-Medina et al., 2020).

Farmers need to access, learn, and use new products, agronomic solutions, innovations, and relevant information from various private and public organizations. Addressing the "last mile" challenges in communication (Boersma et al., 2017) and effective knowledge transfer are vital in the acceptance and utilization of these farming innovations.

Knowledge transfer in agriculture is considered hermeneutic, which is prone to different interpretations. Learning agriculture is complex and dynamic especially in contemporary times with the emerging digitalization as well as advanced innovations and services. However, digitalization poses "last mile" challenges in communication. "Last mile" challenges refer to the problems and issues encountered in both the telecommunications' infrastructure or physical part of the broadband network (NCTA, 2023) and the communication or message flow particularly in rural communities accessing the digital media (Boersma et al., 2017).

Resource limitations such as unaffordability of Information, Communication, Technologies (ICT) hardware and services has been recognized as limitations why mobile agriculture or digital agriculture is not reaching the desired impact. In addition, the desirability and usability of content is low because of limited local applicability and language translation (Flor and Cisneros, 2015). The variations in culture, customs, norms, and socioeconomic factors were found to be the barriers of digital extension services adoption among smallholder farmers in Philippines, Cambodia, and Vietnam. (Le et al., 2024).

Globally, almost half of the population or 3.7 billion people has no mobile internet access, mostly from the low to middle income countries. Fifty three percent (53%) of the population lacks internet connectivity in developing countries while only thirteen percent (13%) compared to developed countries. Gender also plays a factor in the utilization of mobile internet. Women are twenty three percent (23%) less likely to use mobile internet compared to men (Bamford et al., 2021).

National and local government, university extension services, non-government organizations, and private companies face challenges in providing effective and dynamic e-farming advisories due to the gap of evolving digital media relative to the readiness and acceptance of aging farmers. Digital media refer to mobile smartphones, computers, tablets, robots, sensors, Internet of Things (IoT), machine learning, Artificial Intelligence (AI) driven smart technologies, social media, and other forms of digital broadcasts.

Digital media and IoT have been utilized in many cases such as agriculture (Colussi et al., 2024, Mastul et al., 2023, Armenta-Medina et al., 2020, Flor & Flor, 2019, and Flor & Cisneros, 2015). The influence of different communication channels such as social media, mass media, and interpersonal meetings in the adoption of digital agriculture had similarities and differences among farmers in USA and Brazil. The study argues that effective communication channel such as use of social media has higher influence among farmers in Brazil compared to US farmers (Colussi et al., 2024). The potential positive impacts of digital media have been witnessed also beyond agriculture, specifically in the field of social capitalism (Fuchs, 2020) and societal protests (Earl & Kimport, 2011).

The use of digital media in farming of crops is termed E-Farming or Electronic-based Farming for the purpose of this dissertation. This indicates that the E-farming practices or systems involve the use of electronic technology, such as computers, smartphones, and the internet in crop production, marketing, supply chain, and e-commerce.

Internet of Things applications have drastically advanced in contemporary times at the nexus of technology and communication. It features the ability to send data through communication networks (Bayanati, 2023). Internet of Things has three characteristics which include: 1) Networking; 2) Sensing; and 3) Actuators. Record shows that up to 20 billion counts including application in precision agriculture are networked together at home and workplace (Shovic, 2016, Manjunath et al., 2017, Rajeb et al., 2012, and Tripathy & Anuradha, 2018).

Digital media systems and IoT may include activities on:

- *Using digital tools* for crop advisories, monitoring, and market analysis including mobile applications. Site-specific crop management such as detecting nutrient variability based on field maps can improve the yield of crops and its' sustainability impacts (Mastul et al., 2023, Armenta-Medina et al., 2020).

- *Employing sensors and advanced machines* (i.e. unmanned aerial vehicles, robots) to collect data on plant health and environmental conditions like temperature, humidity, and soil moisture, and to utilize in sustainable pest management such as sensor-based weed control innovations. Real-time environmental data of wireless sensor crop monitoring tools enables farmers to optimize irrigation, fertilization, and pest management (Binayao et al., 2023, Mastul et al., 2023, Mulyono et al., 2022, Armenta-Medina et al., 2020).

- *Leveraging online platforms* for social media, e-commerce, information sharing, knowledge exchange, and connecting with other farmers, experts, or agricultural companies (Colussi et al., 2024, Flor & Cisneros, 2015).
- *Machine learning and artificial intelligence* has been advancing rapidly with applications in Agriculture (Mulyono et al., 2022, Armenta-Medina et al., 2020). The use of big data to create specific advisories is transforming farming.

The interface of IoT, machine learning, and Artificial Intelligence brings more value in crop production (Rajput et al., 2023, Mulyono et al., 2022, Sarkar et al., 2022, Sarkar et al., 2021, Khandelwal & Chavhan, 2019, and Das et al. 2018). In 2023, Indonesia had 79% of its' population using internet in mobile phones, which is slightly higher compared to about 76% penetration in the Philippines (Statistica, 2024).

Conventional or traditional way of information sharing and knowledge transfer about farming through face to face or in-person approaches has limitations to reach millions of small holder farmers, especially in the Philippines and Indonesia. The new media and advances in communications and emerging technologies on mobile applications and Internet of Things (IoT) has the potential to be leveraged as agents to address this agricultural challenge (Colussi et al., 2024, Mastul et al., 2023, Armenta-Medina et al., 2020, Flor & Flor, 2019, and Flor & Cisneros, 2015).

Therefore, communication research in the field of e-farming system is key to understand and apply the underlying principles and theories to address the issues on access, efficiency, and effectiveness in crop production and marketing of the commodities. Given the diverse factors or agents interacting in the e-farming system, the complexity theory in communication can discern, clarify, or can be theorized in the e-farming knowledge transfer of digital advisories to marginalized and millions of small holder farmers.

Complexity Theory demystifies how individual simple agents produce complex behavior and system without central control or decentralized self-organization (Mitchell, 2024). The system, which can be biological, technological, or social that improve itself or survive is created by individual agent organized itself in a decentralized way. For example, a termite mound is created because of complex insect interactions among each termite acting as simple agent or node and communicating through chemical signals. Such complex interactions help simple agent to build complex structures and to function differently to adapt and survive. The study of agents in the networks and the interaction is central to the study and understanding of complexity in nature.

According to Mitchell (2024), a complex system has four properties. The first property is the *agent* or simple component relative to entire system. The second property is the *non-linear* or fluidity of interactions among components. The third property *is decentralization* or no central control. Social media use is a typical example of a decentralized and network-based communication approach, which was employed in disaster risk management (Boersma et al., 2017). And the last property is the *emergent behavior*, which is apparent in hierarchical organization, information processing, dynamics, as well as evolution and learning.

Complex system has four core independent disciplines that include *Information, Dynamics, Computation, and Evolution.* These disciplines are brought together in the science of complexity (Mitchell, 2024). Complexity theory has been applied in several societal systems, which include social psychology of neo-diffusionism communication (Chiu & Qiu, 2014), digital social advocacy (McLean et al., 2021), and conflict management (Hendrick, 2009). For instance, complexity theory in digital social advocacy communication provides insight on interdependency of different agents used strategically and theoretically in the development and engagement of social media (McLean et al., 2021).

This dissertation theorizes the four disciplines in Complexity theory in the context of complex system of e-farming knowledge transfers. The individual agents, network of agents, its' interactions, and the emergent behaviors in the e-farming system is central to the study of Complexity theory. In addition, the insights emanating from the marginalized and muted voices of farmers under Critical theory and digital socialism (Fuchs, 2020) is presented in this research.

This study provides an understanding and leveraging Complexity theory and its pedagogy and practice to drive success in e-farming system communications. It is vital to discern the cross disciplinary agents and insights to understand the communication and interactions in the complex systems of e-farming.

Statement of the Problem

Philippines and Indonesia have vast land utilized for agriculture, yet the food production and security remains a challenge. The collaborative works of government, private companies, non-government organizations, research, and extension institutions on the introduction of advanced crop production technologies and services has been progressing and evolving continuously to address such issue.

Communication and knowledge transfer of farming advisories is also taking into new heights in the contemporary times with the potential applications and benefits of IoT and Artificial Intelligence. However, the digital divide between and among the organizations and the marginalized aging farmers is evident. In addition, the digital savvy young generation population who are embracing digitalization are unfortunately not venturing into agriculture.

The “last mile” issues in technology and communications during these digital era hampered the optimal usage and value of digital media in the e-farming system. Such challenges in “last mile” communications persist despite the development and introduction of new agricultural products and technologies. Furthermore, climate change has been impacting crop production negatively.

Research Questions

The research questions of this dissertation include the following, which demystifies Complexity theory of communication on the challenges in e-farming system knowledge transfers in the Philippines and Indonesia.

1. How is information processing of Internet of Things (IoT) under cybernetic tradition converge with the digital advisory communications to marginalized farmers?
2. Why social information and how Complexity Theory in communication can be theorized and be developed into constructs to change the mindset and behavior of aging farmers and to engage new generation farmers through digital interventions?

Objectives of the Study

This dissertation study aims to:

1. Identify and assess different agents and their interactions in the network of organizations and processes in relation to the preparedness and utilization of digital advisories in e-farming system.
2. Determine the social factors and develop construct leveraging Complexity theory to motivate farmers in using digital information to address the critical challenges in farming and to create positive social impact in the society.

Scope and Limitations of the Study

This dissertation study focuses on Complexity theory along with other relevant and associated communication theories such Critical and System theories. This study also provides understanding and application of the Cybernetic tradition in communication.

The organizations assessed in the study are limited to certain public and private entities and responses from selected farmers in the Philippines and/ or Indonesia based on authors' experiences, autoethnography. Furthermore, the scope of digital platforms evaluated in this study is related only to mobile internet, social media, and mobile applications, and did not include other digital approaches such as satellite imagery, digital sensors, and drones or unmanned aerial vehicles (UAV).

Operational Definition of Terminologies

1. Complexity theory in E-farming system – understanding and utilization of complex biological, technological, and/or social systems of digital farming communications involving individual agents, network of agents, interactions, and the emergent behaviors in the field of agricultural crop production and marketing.

2. Digital media - refer to internet, mobile phones, tablets, robots, Artificial Intelligence or AI-driven smart technologies, computers, and other forms of digital broadcasts.

3. Early adopters – agents accustomed and capable to use and drive digital crop advisories.

4. E-Farming or Electronic-based Farming – refer to application and utilization of digital media in crop production, marketing, supply chain, and e-commerce.

5. Exploratory farmers - agents in e-farming system that are undecided but open to digital technologies given sufficient time and information on the value and better appreciation of such technologies.

6. Internet of Things (IoT) - concept in contemporary times that features the nexus of technology and communication having the ability to send data through communication networks.

7. Intermediaries – social agents or actors with different motivations and personas involve in disseminating digital information and advisories.

8. Innovative farmers – agents in e-farming system that are financially capable and motivated to adopt digital media and advanced technologies in their farm operations.

9. "Last mile" challenges - refer to the problems and issues in both telecommunications' infrastructure or physical part of the broadband network and knowledge transfer or communication message flow especially to aging and marginalized farmers.

10. Planning-Communication-Evaluation (PCE) model - proposed model to guide e-farming knowledge transfer system leveraging Complexity theory with various agents, interactions, and emergent behaviors or outcomes in the system.

11. Satisfied farmers - agents in e-farming system that are comfortable and at ease on their existing ways of farming.

12. Wireframing - involves the creation of a basic visual representation of a website or mobile application, which is critical step in planning and design process of websites, apps, and other digital products.

Chapter II

REVIEW OF RELATED LITERATURE

Communication Theories

Complexity Theory emerged extensively in different fields of natural sciences such as biology, computer science, mathematics, physics, and chemistry. This theory underscores the limitations of the Newtonian linear scientific paradigms when applied in complex systems (Hendrick, 2009). Wider applications and importance of Complexity theory have been researched in the field of social science including communication research, management, and leadership (McLean et al., 2021, Chiu & Qiu, 2014, Curlee & Gordon, 2014, and Hendrick, 2009).

Complexity theory demystifies how individual simple agents produce complex behavior without central control, which also means decentralized self-organization (Mitchell, 2024). The system is created by individual agent organizing itself in a decentralized way. It can be biological, technological, or social that improves itself, adapts, or survive. The agents or nodes interact and can build complex structures that functions differently such as adaptation and survival. The study of agents in the networks is central to the study in understanding the complexity in nature.

According to Mitchell (2024), a complex system has four properties, which include:

1. Simple agents or components
2. Non-linear interactions or not proportional
3. No central control or decentralized
4. Emergent behaviors

The first property is the *agent* or simple component relative to whole system. The agents are also called nodes that comprises the complex system. In agriculture farming system, different agents can be identified that include the organizations who are the sources of advisories, platforms or cyber extension tools, and their extension agents responsible for the dissemination of such advisories (Rathore & Sumanth, 2021, Qamar, 2012, and Tiraieyari et al., 2013).

In the Philippines, among the organizations providing advisory services or extension services are public institutions including Department of Agriculture (DA) and its' Bureaus, Agricultural Training Institute, local government units, state universities and colleges, private sector, non-governmental organizations, farmer-based associations, and cooperatives (Table 1) (Qamar, 2012). Although, there are other public and private organizations not listed in this table.

Table 1. *List of agencies and organization providing advisory services in the Philippines.*

Organization Group	Specific Agency, School, or Organization
DA Bureaus	• Agricultural and Fisheries Product Standards • Agricultural Research • Post-Harvest Research and Extension • Soils and Water Management
DA Autonomous Agencies	• Agricultural Credit and Policy Council • Cotton Development Administration • Fertilizer and Pesticide Authority • Philippines Coconut Authority • Sugar Regulatory Commission
State Universities and Colleges	• Benguet State University, La Trinidad, Benguet • Central Luzon State University, Munoz, Nueva Ecija • Central Mindanao University, Maramag, Bukidnon • Central Philippine University, Iloilo City, Iloilo • Mindanao State University, Marawi City, Lanao del Sur • Pampanga Agricultural College, Magalang, Pampanga • University of the Philippines Los Banos, Laguna • University of the Philippines Visayas, Iloilo City, Iloilo

	• Western Mindanao State University, Zamboanga City, Zamboanga del Sur
Private Universities	• University of Saint La Salle, Bacolod City, Negros Occidental • Liceo de Cagayan University, Cagayan de Oro, Misamis Oriental • Silliman University, Dumaguete City, Negros Occidental • Universidad de Zamboanga, Zamboanga City, Zamboanga del Sur • De La Salle Araneta University, Malabon City, Metro Manila • University of Mindanao, Davao City, Davao Region • Misamis University, Ozamiz City, Misamis Occidental
Non-governmental organizations	• Center for Agriculture and Rural Development, Inc. (CARD) • Japan Agricultural Exchange Council (a Japanese NGO with office in the Philippines Mindanao Baptist Rural Life Center • Infanta Integrated Community Development Assistance, Inc. (ICDAI) • Negros Island Sustainable Agriculture and Rural Development Foundation (NISARD) • Organic Certification Center of the Philippines (OCCP) • Palawan Center for Appropriate Rural Technology, Inc.
Farmer-based associations	• Federal Farmers Association of the Philippines • The Pilipino Banana Growers and Exporters Association (PBGEA) • Farmers' and Producers' Business association of the Philippines, Inc. (FAPBAPI) • Farmers Association for Rural Upliftment (FARU) • Tongonan Farmers Association (TOFA) • Davao Hog Farmers Association (DHFA) • Misamis Oriental Farmers' Association (MOFA) • Camalandaan Agroforest Farmers Association • Organic Producer Trade Association
Cooperatives	• 8th Brigade SAWDARA-MNLF Agricultural Producers Cooperative • Abalos Estate Agricultural Credit Cooperative • Agpangi/ Cabungahan Small Farmers Multi-purpose Cooperative • Agriculture Farmers Credit Cooperative • Alcala Livestock Raisers Multi-purpose Cooperative • Philippines Coconut Farmers' Cooperative • Primera Producers Cooperative

The second property is the *non-linear* or fluidity of interactions among components. There have been criticisms raised on the common understanding that having small input leads to small output and having large input produces large output. Researcher argues that a non-linear pattern and different outcomes occurs in a complex system. Such outcomes in the interactions are difficult to predict by studying individual agents only (Hendrick, 2009).

The third property *is decentralization* or no central control. The individual agents function accordingly without the influence of central control factor. This is property is also called self-organization (Hendrick, 2009). Agents are interacting within a system to produce new order along the process without any external governing factor or agency. Such outcome is both uncertain and irreversible because of its' self-organizing properties.

The fourth and last property is the *emergent behavior*. The emergent properties or structures that arise from individual agents are greater than the sum of its individual agents. This emergent behavior is formed during the process of self-organization making the production of structures or patterns difficult to predict (Mitleton-Kelly, 2005). This property of complex system is evident in hierarchical organization, information processing, dynamics, evolution, and learning.

Complex system has four core disciplines – 1) *Information, 2) Dynamics, 3) Computation, and 4) Evolution.* These disciplines are independent and brought together in the science of complexity (Mitchell, 2024). The first discipline is Information, wherein it evaluates representation, symbols, and communication. The second discipline is Dynamics wherein complex system is analyzed continuously with change in structure and behavior of the systems. The third discipline is Computation, wherein it evaluates how systems process information and act on the results. And lastly, Evolution that evaluates how system adapts to environment that changes constantly over time.

Some examples of complex systems are brain, body organs, food web, economies, and social network of human connections (i.e. friendship relationship and so on having patterns of biological and technological networks). The connectivity and kinds of links in such network can have big effect on the stability of the changes of each node or agent.

The study of cities is another example of complex systems. The city resembles like a living organism in many ways in terms of why it grows and scale in size and how it operates. These are the questions forming the basis of complex system research. Understanding how those patterns are formed provides discourse in Complexity theory.

The goal in complex research is to study cross disciplinary insights to understand complex systems. These can be tested methodologically through experimental work, theoretical work, and computer simulation. There are many measures of complexity such as Shannon information, fractal dimension, algorithmic complexity, logical depth, thermodynamic depth, effective complexity, and degree of hierarchy (Lloyd, 2001).

Hendrick (2009) explains the pedagogy and broader applications of Complexity theory in social sciences covering sociology, international relations, social psychology, development, management, military theory, lost in translation, and transdiciplinarity. Complexity theory has been applied also in several societal systems, which include social psychology of neo-diffusionism communication (Chiu & Qiu, 2014), technology-based communication, program management, and leadership (Curlee & Gordon, 2014), digital social advocacy (McLean et al., 2021), and conflict management (Hendrick, 2009).

Complexity theory in digital social advocacy communication provides insight on the interdependency of different agents used strategically and theoretically in the development and engagement of social media (McLean et al., 2021). The properties and disciplines of Complexity theory is theorized in the field of e-farming advisory communications to marginalized farmers. Discourses about the muted voices of farmers falling under the critical theory are considered part of the agents in the knowledge transfer e-farming system.

Critical theory is a form of pragmatic constructivism that involves contrasting tacit assumptions of discursive systems and power driven by more control of one's life (Fleming, 2012). Communication in contemporary times produces the sociality and reproduces the society through mediation of capital, influence, and reputation under digital capitalism (Fuchs, 2020).

Critical theory (Fleming, 2012) and Cybernetic tradition (Wiener, 1948, Turing, 1950, Weiner, 1985, and Craig, 1999) are relevant to evaluate the agents, network of agents, interactions, and emergent behaviors in the communication of digital advisories and IoT in e- farming and food production system. The social, cultural, and technological agents vis a vis knowledge transfers are part of theorizing the complex e-farming system aimed to address the research questions of this dissertation.

The dissertation does not focus only about the content, information flow and effectiveness of digital interventions but rather aims to unravel perspectives of different agents or social actors and their' interactions, especially on the aspect of behavioral change. These agents are important in the study to ensure e-farming communications can serve as catalysts of growth and development in the agriculture sector.

Digital Media and Agricultural Communication

Digital media or cyber extension tools broadly consist of mobile phones, personal computers, the Internet, e-mail, imaging technology, digital audio-video, call center & satellite communication network, file transfer protocol, Telnet or Local Area Network (LAN), expert systems (intelligent computer program) and other forms of digital broadcasts (Flor & Cisneros, 2015, Flor 2014, and Rathore & Sumanth, 2021).

Social media, mobile applications, and crop modeling advisories digital platforms have been utilized by farmers especially in developed countries. However, these digital platforms and models are still not available or have limitations in developing countries like Philippines and Indonesia (Bachtiar et al., 2024). In recent years, farmers in these countries have utilized social media platforms given its' interactiveness and popularity.

Based on literatures, traditional approaches such as brochures, print media, Farmer Field Days, and School On Air (Kassem et al., 2019 and Estrada et al., 2021) as well as advanced digital approaches such as e-mail, world wide web (www), expert systems of extension (computer program), video conferencing, call centers and satellite communication network, news and discussion groups, and webinars (Rathore et al. 2021) have been utilized as communication approaches to provide agronomic advice to farmers.

In the Philippines, e-farming communications of Department of Agriculture is done through online courses, contact center services, and Farmer Field School (FFS). Farmer Field School that considers the cultural norms and highlights farmer to farmer and village-level communications has been proven as effective communication approach (DA ATI, 2023).

In Indonesia, the crucial role of extension workers in disseminating agricultural information was emphasized. The study highlights the importance of using educational strategies that are designed specifically on local context, as these can significantly impact the effectiveness of agricultural extension programs (Rony & Heryadi, 2024). WhatsApp which is available as mobile or web-based application serves as a valuable platform. This free communication platform enables extension workers and farmers to engage in discussions, debates, and consultations. This interactive environment fosters greater participation, facilitates counseling on agricultural matters, and ultimately contributes to increased agricultural product output and marketing success (Madonna et al., 2023).

In other Asian countries like India, cyber extension practices for smallholder farmers were utilized to enhance e-farming knowledge transfers. These digital communications and infrastructure readiness include the following (Chattopadhyay, 2012):

- **Email-based communication:** Facilitating interaction among extension workers, scientists, and farmers.
- **Information services:** Providing news, updates on government programs, and poverty alleviation programs or schemes.
- **Question and answer forum:** Connecting farmers with experts for crop advisories and support.
- **Database management:** Creating and maintaining statistical databases.

- **Website hosting:** Providing online resources for agricultural extension institutions.
- **Internet access:** Offering internet connectivity through agriculture and rural development offices and cyber cafes.
- **Multimedia content:** Providing video demonstrations and audio files for educational and extension purposes.
- **Online training:** Conducting group-based online classes for farmers.

In terms of advisory contents or topics, the following factors were important to smallholder farmers in India – commodity or product-based market intelligence, integrated watershed management, delineation of efficient cropping zones to sustain production, development of decision support systems for management of biotic and abiotic stresses, development of comprehensive portals for high value crops, and precision farming techniques for commercial and high value crops (Chattopadhyay, 2012).

Mayer (1997) had shown that delivery media, presentation modes, and sensory modalities must be considered in knowledge transfers to have an immersive learning. Multimedia learning with enhanced visualization is more effective than verbal explanation. Experiential and collective learning approach has also been identified to ensure success in the adoption of agricultural practices, i.e. Integrated Pest Management methods (Palis, 2006). Moreover, the inclusion of social learning in communication strategies improves the effectiveness of agricultural extension services (BenYishay and Mobarak, 2013). Understanding the socio-demographic and dynamics among farmers can lead to a higher adoption rate of technology.

In summary, e-farming knowledge transfers can be a valuable solution to overcome the geographical limitations of traditional face-to-face communication (Rathore & Sumanth, 2021, Flor & Cisneros, 2015, and Flor 2014). The incorporation of local social context combined with experiential learning has the potential to increase adoption of e-farming advisories.

Crop Importance in the Philippines and Indonesia

The key important crop in the Philippines includes rice (4.8 million hectares), coconut (3.6 million hectares), and corn (2.6 million hectares) in terms of area comprising a total of 11 million hectares (PSA, 2023). These three crops comprise at least 80% of the arable agricultural areas in the country. In terms of export importance, coconut as coconut oil (valued at USD 1.43 billion), banana as fresh fruits (USD 1.14 billion), and pineapple products (USD 769.94 million) are the top crops. Banana and pineapples are mainly driven by private corporations. As such, the private cyber extension initiatives, or public – private partnership model is vital in conducting extension or knowledge sharing such as in the case of India experience (Rathore et al., 2021). The Philippine government expenditure in the agriculture and agrarian reform sector was PhP 143.36 billion pesos (PSA, 2023).

In Indonesia, rice and corn are the major crops along with palm oil, coconut, cassava, and rubber (BPS Statistica Indonesia, 2023). Palm oil is the main crop with estimated harvested area of 14 million hectares. This is followed by rice with 11.2 million hectares and corn with 3.8 million hectares (US FAS, 2024).

Digital Agronomy Opportunities, Limitations, and Social Challenges

Crop advisories are important to farmers for them to grow their crops productively and profitably. However, it is unrealistic to reach millions of farmers with limited resources of the government extension agencies and private companies. In India, one extension worker is challenged to cover 1,162 farmers (Rathore & Sumanth, 2021). With the dramatic surge of internet and advanced digital platforms, the potential of these technologies to reach millions of smallholder famers can be realized.

The rise of smartphones and internet has advanced digital platforms in contemporary times, from internet & computers into internet & social media mobile applications, augmented reality and virtual reality, and sensors in drones. In the Philippines and Indonesia, the most common digital social media platforms used are Facebook, YouTube, WhatsApp, Instagram, and Tiktok (Statistica, 2024, Nurhayati-Wolff, 2024, Dixon 2024, and Balita, 2024). Indonesia is the third highest users of Facebook while Philippines ranks sixth globally (Dixon, 2024).

The Philippines, with about 50.94 million users of smart phones had the longest average time usage, estimated at 9 hours per day and (Balita, 2024). In Indonesia, the top social media platforms are WhatsApp, Instagram, Facebook, and Tiktok (Nurhayati-Wolff, 2024). These digital platforms are accessible either using web-based browsers in computers and/ or as downloaded mobile applications. There are also available digital agronomy mobile application platforms in rice, corn, and vegetables available in both countries.

In the Philippines, among the common digital mobile applications were developed by government agencies such as Department of Science and Technology, National Crop Protection Centers, University of the Philippines Los Banos, and several private multinational agribusiness companies such as Bayer, Syngenta, and Atlas. Among these mobile applications include AgriDoc, Binhing Palay, eDamuhan, Fertilizer Expert, SpidTech, Adviser, and Tiwala.

In Indonesia, the available agricultural digital contents and mobile applications are focused on farming advisor, soil test services, farm input marketplace, financing, and direct market linkage of farmers to market. TaniHub, Semaai, Sayurbox, Eden Farm, Jala, and IGrow are some of these platforms (Humana, 2024 and InvestinAsia, 2024). Global organizations like International Rice Research Institute (IRRI) and Centre for Agriculture and Bioscience International (CABI) also developed Plantwise and rice Doctor mobile app, respectively (IRRI, 2024, and CABI, 2024). These are used to provide e-farming advisories to farmers and extension agents in different countries.

Despite digital farming innovations, the utilization of mobile applications remains a challenge. For instance, less than 1% of rice farmers have used the PhilRice app in the last five years. There are also existing digital agronomy advisories such as contact center & online training tools (DA ATI, 2022) and emerging advisories with IoT alert systems, drone usage, and cloud-based real-time decision-making tools (Binayao et al., 2024 and Mulyono et al., 2022).

The technology-averse mindset and attitude have slowed down the adoption of digital advisories among farmers (Bachtiar et al., 2024). Digital agronomy infrastructure, platform, and communication remain a challenge and will continue to be the hurdle in crop production. In Indonesia, a key implication of a study is to implement information and communication technology development policies, such as constructing base transceiver stations (BTS) in areas with limited internet access. (Irawan et al., 2024). Several research also highlighted the opportunities in driving the digital advisories (Mohamood et al., 2017, Qamar, 2012, and Tiraieyari et al., 2010).

Educating and empowering the new generation farmers to produce food remains a challenge in the Philippines. Only thirty five percent (35%) of farmers wanted to have their children continue rice farming due to the following reasons: 1) ensure food on their family's table, 2) source of family's income or additional income, and 3) only option for livelihood of their children (Palis, 2020).

Digital advisory communication ecosystems to marginalized farmers are still muted under Critical theory. Among the reasons may include the difficulty of digital access that requires financial and knowledge investments. In addition, marginalized farmers are not just interested on digital agronomy advisories but also in financing and insurance programs that lower their risks associated in crop production.

Despite these challenges, digital communication is inevitable and is becoming part of people's lives including farming activities. The identified needs and challenges need to be prioritized in developing and enhancing utilization of digital advisories. These advisories, interplay of social actors, and other social aspects including behavior and culture should be studied. Thus, the need for communication research is required.

In Indonesia, a study underscores that youth are often perceived as more innovative and adaptable than older generations of farmers, who are sometimes characterized as resistant to change or unable to adopt new technologies. The prevailing belief that young people are more efficient and productive in agriculture has influenced national policies aimed at enhancing food security and agricultural productivity (Toumbourou et al., 2023). Moreover, there was 36% increase on the number of agricultural companies venturing into agriculture with 5,705 companies from 4,209 companies despite decrease in the number of farmers (BPS Statistica, 2023).

Chapter III

FRAMEWORK OF THE STUDY

Considerations of Relevant Communication Theories

Complexity Theory, Network Theory, System Theory, Critical Theory, and Social Network Analysis are relevant theories that can help address the research questions pertaining to digital crop farming in Agriculture.

Complexity Theory originates from chaos theory or areas that are on the *edge of chaos* (Wheatly, 1999). The chaos theory was originally proposed by meteorologist Edward Lorenz highlighting the phenomenon on the theory of butterfly effect. One flap of wings will have different effect on the environment and on the whole ecosystem.

Complexity theory rationalizes how individual and simple agents produce complex behavior, patterns, or structures through self-organization and producing emergent behaviors (Mitchell, 2024, Curlee & Gordon, 2014, and Hendrick, 2009). The system is created by individual agent organizing itself in a decentralized way. It can be biological, technological, or social that improves itself, adapts, or survive. The agents interact and can build complex structures greater than the sum of all individual agent that can function differently such as adaptation and survival. As such, understanding the complexity in nature requires the study of the agents in the networks.

Complex systems are said to be open systems where agents have observable exchange of energy and information with their environment. These agents in the systems interact and adapt to the behavior of other agents (Hendrick, 2009). Complexity theory has been applied in natural sciences. However, Curlee and Gordon (2014) highlighted its' application on social sciences, particularly focusing on the impact of a single leader making a difference.

Connectivity in the context of networking is an attribute of complex systems. The operation of networks that are contradictory is embedded within a complexity context. Network studies have developed to explore connections between agents relative to their number and strength. More connectivity within complex systems also increases the opportunities for exchange of information and adaptiveness for change and development. This is closely linked the next relevant theory, the Network Theory.

Network Theory, that is another useful theory detailing the different elements interconnected with a link and as its elements interact in the network. This could be applied to content management, delivery, and effectiveness. Analyses can be done on content development and how the content is organized in the system.

Network theory also refers to behaviors that can be understood socially (Stohl, 2018). The behaviors on how farmers react and connect to new and digital ways of farming is an example of this. The interactions of every social unit like farmer and the organizations creating e-farming advisories need to be analyzed.

System Theory can provide a holistic view of systems and their interactions in communication (Krippendorf, 1985) (Table 2). This theory has been used widely in strategic planning of an organization. Analysis focuses both on internal views and expands to external views of the system. Strengths, Weaknesses, Opportunities, and Threats analysis considers both internal and external perspectives.

Systems theory aims to explain the dynamics and functions of the whole systems or networks and their parts, and how to change the systems effectively (Banathy, 1996). Bertalanffy (1968) stated that general systems theory assumes isomorphic relationships between different levels of an organization, which include boundaries, transfer of information, and homeostatic and self-organizing tendency of a social group. This self-organizing dynamism and functionality in systems theory is similar with complexity theory where agents create complex structures in a decentralized approach arising from self-organization.

Table 2. *Communication systems causal interactionism*

Communication In:	*Observed Systems*	*Systems Involving Their Observers*	*Systems of Production*
Closure Property	Informal Closure	Descriptive Closure	Organizational Closure
Linear Communication	Linear Causal. Chains	Process of Description (of Distinctions and Relations)	Process of Specifying (Organization of Allopoietic Production)
Recursive Communication	Circular Causal. Loops	Process of Self-referential Description	Self-production
Information	Reduction of Variety	Increase in Stability, Conformity, Compliance with Description	Increase in Efficiency (in Time and in Space of Organization)
Emerging Equilibrium	Homeostasis	Stable Description of and by the System	(Stable) Autopoietic Organization
Emerging Form	Independent Subsystems of Interdependent Components	Constitution of Contrasting Identities (of Components)	Autonomy

Critical Theory of communication draws a discourse on Marxist humanism counter-narrative, counter-theory, and counter-politics to neoliberalism, new authoritarianism, and postmodernism (Fuchs, 2020). Critical theory involves essential thinking that includes a disengagement from the tacit assumptions of discursive practices and power relations and to exert more control over one's life. In addition, this theory attempts to provide people with knowledge and understandings as well as planned action designed to free the subjects from oppression (Fleming, 2012). This theory analyzes the muted voices of marginalized farmers in the study.

The convergence and divergence of Marxist-humanist theory and the Critical theory of communication on Habermas theory of communicative action focused on hegemony and ideology critique providing a discourse on digital socialism (Fuchs, 2020), which is relevant to e-farming communications.

Social Network Analysis aims to understand the relationships and connections of different relevant and influential actors within a social system (Carvalho, 2020, BenYishay & Mobarak, 2013, Ramirez, 2013, Van Dijk, 2012, and Banathy, 1996). Farmer being the agent as described in Complexity theory or part of the whole cropping value chain or social system is central to this study. There are various societal direct and indirect relationships among the stakeholders centered towards farmers as the end-user of digital advisories. These networks of stakeholders interacting with the farmer include government, private companies, extension services, research institutions, Information Technology providers, and non-government organizations. The Social Network theory can lead into pragmatism of communication and usefulness in addressing the plight of marginalized farmers.

Theorizing Communication and Improvements in Communication Research

Complexity Theory investigates the different agents, interaction, and emergent behaviors or patterns in transferring knowledge of digital crop advisories in an e-farming system. McLean (2021) utilized complexity theory in digital social advocacies. Chiu and Qiu (2014) studied the social psychology of neo-diffusionism communication while Hendrick (2009) utilized this theory in conflict management. Complexity theory aims to provides insight on interdependency of different agents used strategically and theoretically in the development and engagement of e-farming advisories in social media and mobile applications.

This study about knowledge transfers of e-farming advisories evaluates both the organization creating the digital advisory contents and the end-user farmers who are marginalized under the scope of Critical theory. The incorporation of Critical theory of media and technology explores the relationship and interactionism of the planned digital agronomy and the target stakeholders. Critical Theory of technology highlights the role of cultural and social values in the technology itself (Eustaquio, 2021). Dialectical reasoning in this theory allows multidimensional views and perspectives of the causal relationship of media or technology and society. For instance, how digital representation in different formats like text, sound, image, or video can be achieved. The proposed dissertation aims to unravel the potential of digital media and technology that may have multiple potential effects to farmers and social systems.

Related to Critical media and technology theory, the Foucault postmodernism puts emphasis on the proclamation of the 'death of man' and development of new perspectives on society, knowledge, discourse, and power thought (Best & Kellner, 1991). This is particularly true with the digitalization era during this time. Telephone and analog mobile phone used by people changed into smartphone, which has more immersive functionalities and better connectivity because of Internet of Things (IoT). This development has changed the cultural landscape globally. Such devices and other related technologies simplify the work of people.

Cybernetic tradition considers information processing including relationships among the various elements of the system (Craig, 1999). This tradition has implication in this planned dissertation on e-farming and digital advisories that can help farmers, regulators, and different companies to ensure sustainable food in our table.

Given the complex system in e-farming knowledge transfer, Systems theory can also be leveraged. This has been used to study organizations' operations and information processing. The organization, as a social system, receives input from its environment to include farmer and various organizations. Then, it translates these inputs through conversion process into outputs, such as decisions, policies, programs, products, services, etc. These outputs affect future inputs to the organization through feedback. Feedback loops can also be positive reinforcement that further encourages the system's activity or negative reinforcement that balances or discourages continued activity.

Furthermore, Network theory has been found useful in organizational communication and is relevant to this research study. Digital Agronomy developers need to understand the target stakeholders such as farmers in the system. Understanding the communication in the network can generate useful insights and theories for the achievement of desired goals.

Complexity theory incorporates these relevant theories in understanding the agents and the whole system. As a summery, this study provides understanding on the theory, pedagogy, and practical applications in knowledge transfer of e-farming advisories.

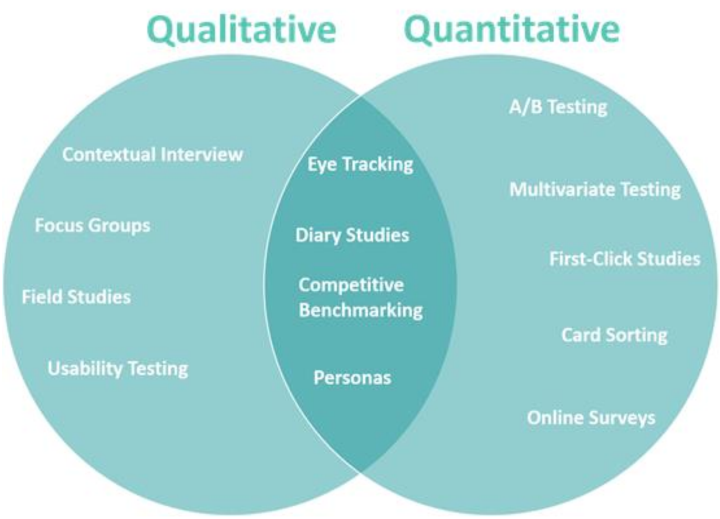
Chapter IV

METHODOLOGY

Research Approach and Design

A combination of quantitative and qualitative research design was employed in this study on knowledge transfer of e-farming communications. Desktop research was used for quantitative design while Focus Group Discussion (FGD), interviews, and usability testing were used for qualitative research design (Figure 2) (Guillory, 2020).

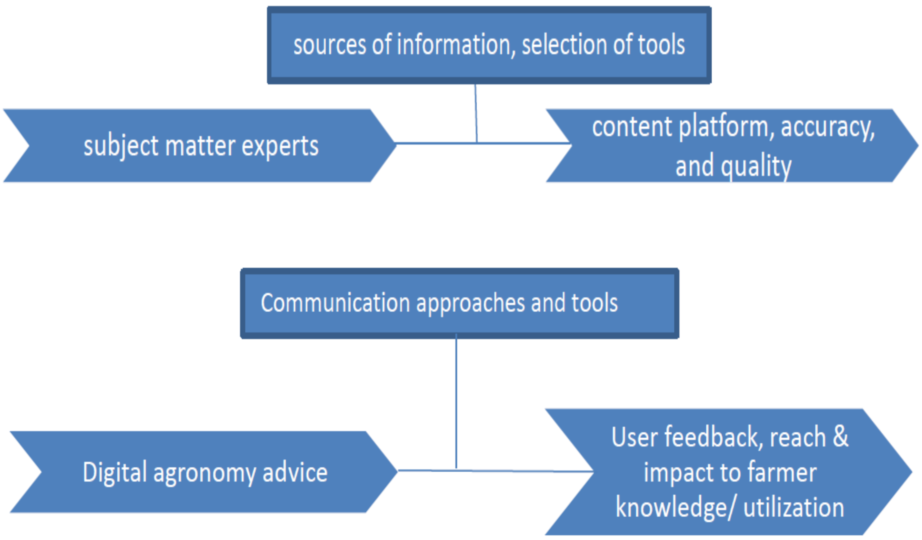
Figure 2. *Nexus of different design approaches in quantitative and qualitative research.*



For desktop study, the use of internet, social media research, and autoethnography were employed to determine the available e-farming advisories focused on mobile applications and social media accounts. The descriptive information, utilization, and analysis of e-farming digital advisories and platforms of relevant government agencies and private organizations were evaluated.

Organizations creating the digital advisories were evaluated based on their strategic intent, processes or operating procedures, systems, content creation, content platform, knowledge transfer or communication approaches, utilization, success factors, and recommendations (Figure 3). The study examines how the organizations create the topics, accuracy and quality of the content, kind of media (i.e. text, symbols, infographics, voices, podcast, videos), type of platform (i.e. internet, mobile application, social media application), and communication delivery (i.e. digital communications like website and mobile & social media)

Figure 3. *Communication process flow from content creation of organizations to utilization or success metrics of end user farmer.*



Qualitative research design was also utilized to collect and analyze data, to theorize communication theory, and to develop new communication constructs, frameworks or theories. Key characteristics of qualitative research as described by Creswell (2013) were used as guide during data collection and analyses. These include natural setting, researcher as key instrument, multiple sources of information, inductive and deductive data analysis, participants meaning, emergent design, reflexivity, and holistic account.

Qualitative research using autoethnography approach was conducted through Key Informant Interview (Mumtaz et al., 2014), stakeholder and farmer contextual interviews, Focus Groups Discussion, and Usability Testing (Guillory, 2020). These were done by observing the participants, by probing methods and using interview guides, and by generating field notes to generate meanings from the experiences of the social actors (Lindlof & Taylor, 2011). This communication research on e-farming focuses on the depth of meaning and people's experiences as well as the process of creating the meaning from activities, situations, and objects (Leavy, 2017 and Anderson, 2009). In Complexity theory, the meanings from the agents, their interactions, and emergent behaviors are evaluated.

The qualitative research of this dissertation analyzes relevant major traditions in communication, primarily with the purpose of understanding the meaning behind the action but differ in locating the meaning of the action (Lindlof and Taylor, 2011):

1. Phenomenological tradition that locates the meaning in the essence of experience.
2. Symbolic Interactionism where meaning is in the interaction.
3. Ethnography where meaning is in the culture.
4. Ethnomethodology that locates meaning in the practice, and
5. Critical theory wherein the meaning is contested, i.e. marginalized versus dominance.

The meanings and interactions of the different agents in the e-farming system based on the experiences of content developers and farmer end-users were evaluated and analyzed utilizing the Complexity theory in communication (Mitchell, 2024, McLean et al., 2021, and Hendrick, 2009).

Setting and Sampling Methodology

Literature search on crop economic importance vis a vis digital crop agronomy advisory was carried out. Research questions, interview guide, and probing approaches from Lindlof and Taylor 2011 were designed and used to get information and insights from the organizations developing the e-farming contents, and from the farmer accessing the advisories. Ten key informants in the private sector (Bayer Crop Science) and public sector (National Crop Protection Center, University of the Philippines Los Banos) in the Philippines were carried out. One hundred farmers with fifty (50) farmers covering eight (8) provinces in the Philippines and fifty (50) farmers in six (6) provinces in Indonesia were interviewed either one-on-one or in a focus group discussion (Table 3).

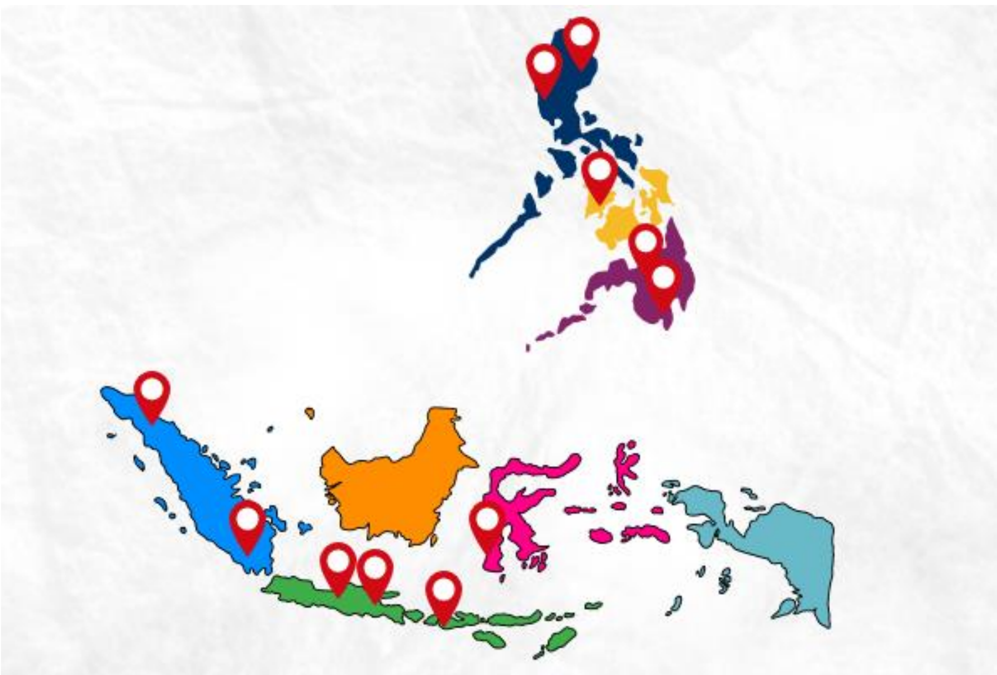
Autoethnography, Focus Group Discussion (FGD), and Key Informant Interview (KII) in rice and corn areas in the Philippines and Indonesia (Figure 4) were utilized in this study. The farmers interviewed in the Philippines were in the provinces of Isabela, Pangasinan, and Tarlac in Luzon island, provinces of Iloilo, Capiz, and Kalibo in Visayas island, and Misamis Oriental, Bukidnon, and South Cotabato in Mindanao island. In Indonesia, farmers were interviewed with the help of Indonesian translator or interpreter in the provinces of North Sumatra (Medan & Karo regency), South Sumatra (Lampung), Central Java (Solo/Surakarta, Grobogan regency or kabupaten), East Java (Surabaya, Nganjuk, Kediri, Jombang, and Jember regencies), South

Sulawesi (Makassar, Maros and Jeneponto regency), and East Nusa Tenggara (Lombok and Sumbawa).

Table 3. *Number and locations of farmer respondents interviewed in the study.*

Stakeholder/ Country	Province	City/ Town/ Kabupaten	No. of Farmers
Farmers in the Philippines	Isabela	Cauayan, Angadanan	6
	Pangasinan	Manaoag	2
	Tarlac	Concepcion	2
	Iloilo	Sara, San Dionisio	4
	Capiz	Dumarao	2
	Kalibo	Banga	20
	Misamis Oriental	Claveria	2
	Bukidnon	Malaybalay	2
	South Cotabato	Banga	10
Famers in Indonesia	North Sumatra	Medan, Karo	6
	South Sumatra	Lampung	2
	Central Java	Solo (Surakarta), Grobogan	6
	East Java	Surabaya, Nganjuk, Kediri, Jombang, Jember	20
	South Sulawesi	Makassar, Maros, Jeneponto	8
	East Nusa Tenggara	Lombok, Sumbawa, Bima	8

Figure 4. *Geographical locations of farmers covered during the autoethnography research on e-farming knowledge transfer.*



Participant observation and field notes were utilized in collecting data (Lindlof & Taylor, 2011). This approach ensures enhancement of skill at performing the routine practices as a researcher and creates a vivid, detailed, and relevant accounts of experience. Field note is the source of knowledge, which is gained from the observation of social action and reflection as participants perspective. In interviewing, certain techniques were utilized with consideration on the interview context and recording, developing rapport, and active listening.

Data Collection and Analysis

Rice and corn farmers were prioritized as target respondents since these are the key crops in the Philippines and Indonesia. Philippines is predominantly into rice farming with about 4.7 million hectares (PSA, 2023) while Indonesia has 11.2 million hectares of rice (US FAS, 2024). Available platforms and communication approaches on agricultural mobile applications developed by different public and private organizations were evaluated. Framework and recommendations were developed from the data gathered to help improve the acceptance and utilization of e-farming advisories.

Autoethnography, Key Informant Interviews, and Focus Group Discussion were utilized for this qualitative research. The respondents include mobile application developers from government and private companies as well as 100 farmers in the Philippines and Indonesia (Table 3). The data and information of the study were gathered from the said agents of e-farming system from August 2023 until July 2024.

The first part of data collection was desktop research on the available digital agronomy platform. This was done by identifying government and/ or private companies that utilizes digital media in providing advisories to farmers. Social media and mobile applications of public and private companies were also assessed. Data were analyzed using descriptive statistics.

The second part of data collection was the conduct of qualitative research through Autoethnography, Key Informant Interviews and farmer Focus Group Discussion to understand the factors critical to the creation and communication of the content as well as the farmer situation. Meanings were generated from the data and information from the expert key informants and experiences of farmers.

Farmer were asked using research questions following interview guide and probing approaches from Lindlof and Taylor (2011). For qualitative data analyses, categorization was developed based on the responses and codes in each category and followed by interpretation using themes (Lindlof and Taylor, 2011). Interpretation is the translation of an object of analysis from one frame of meaning (i.e. categorization codes) into another.

- What is your experience in farming?
- How did you get the information about agronomic practices on crop production?
- Do you have any preference or suggestion about the methods or approaches in getting agronomic advice or other concerns in farming?
- What are your thoughts or important considerations to make your farming successful?
- Can you share any experience of using digital tools in accessing agronomic advice? Is it helpful, why or why not?
- Are you willing to try new digital tools such as mobile applications to help you in farming?

- What are the critical factors that need to be considered or developed to encourage you to use digital applications?
- Do you have suggestions on how we can encourage your children or children of other farmers to continue farming?

Organizations and companies that developed and launched digital content advisories were evaluated. These include public organizations such as Department of Agriculture, Department of Science and Technology, University of the Philippines Los Banos National Crop Protection Center, and private organizations such Bayer Crop Science and Syngenta Philippines who are input providers of seeds and pesticides crop products, and Atlas company who provides fertilizer inputs to farmers.

Triangulation was done to ensure reliability of interpretations. This technique compares two or more forms of evidence particularly responses in different locations in relation to the object of research interest such in the case of digital agronomy platform to farmers. The sources came from the fieldnotes, interviews, and other qualitative evidence.

Ethical Considerations

Ethical and related policies of the various organizations and respondents interviewed for this dissertation were complied. Similarly, ethical policies of the University of the Philippines Open University were strictly followed to protect all the respondents and stakeholders involved in the conduct of the dissertation study.

Chapter V

RESULTS AND DISCUSSION

Based on the data derived from Key Informant Interviews, Focus Group Discussion, and Desktop research, there are different social agents identified and emanated into discursive communication of e-farming crop advisories. Meanings were derived and developed into constructs based on Complexity theory in communication and based on Critical and Network theories. The study theorizes these communication theories to ensure attractiveness of digital media among farmers. In addition, recommendations on communication strategies were developed to address the problems of the muted and marginalized farmers.

The results of this dissertation research provide discourse on Complexity theory, pedagogy, and practical applications of knowledge transfer and communications of e-farming. Specifically, this study provides understanding of the preparedness and programs on digital crop advisories available to farmers. In addition, this study proposes and recommends framework consisting of social actors and factors also called agents or nodes and their interactions as defined in Complexity theory. The research aims to leverage Complexity theory in developing and communicating e-farming knowledge to motivate farmers and encourage new generation of farmers to use digital information to address the critical and “last mile” challenges in farming.

Research Question 1. How is information processing of Internet of Things (IoT) under Cybernetic tradition converge with the digital advisory communications to marginalized farmers?

The strategic directions, funding, and cross-discipline team or organizations are key agents to the success of digital advisories. The extent or scale of digital advisories project influences the funding and aspirations. The simplicity and complexity of the functionalities affects the time and investment of the development.

Organizations may consider developing all contents and infrastructure needs internally such as internal team development and hosting. The benefit of this approach is the priority and confidentiality of the information, which are secured. However, this requires more budget. Other organizations find and collaborate with external IT companies or even utilize open source and free digital mobile applications.

Based on the interviews from organizations that develop digital mobile advisories, there are two key agents or considerations:

- Resource persons or experts – these are the agents in digital advisory creation are create the information, knowledge, or materials containing the communication messages and media types that will be delivered to the intended stakeholders.
- IT or computer science experts or engineers – these are the agents that develops user front -end interface such as mobile application and the backend configuration that can be hardware, software, or cloud-based architecture that will incorporate, upload, or process the information and different types of media.

Organizations may utilize third party service providers like Pimcore to develop the content and digital platforms. The Pimcore Plattform empowers different companies and organization to improve sales operations, marketing, digital commerce, and customer experience. The company develops software that can be used in front end interface like websites, online shops, applications and digital portals.

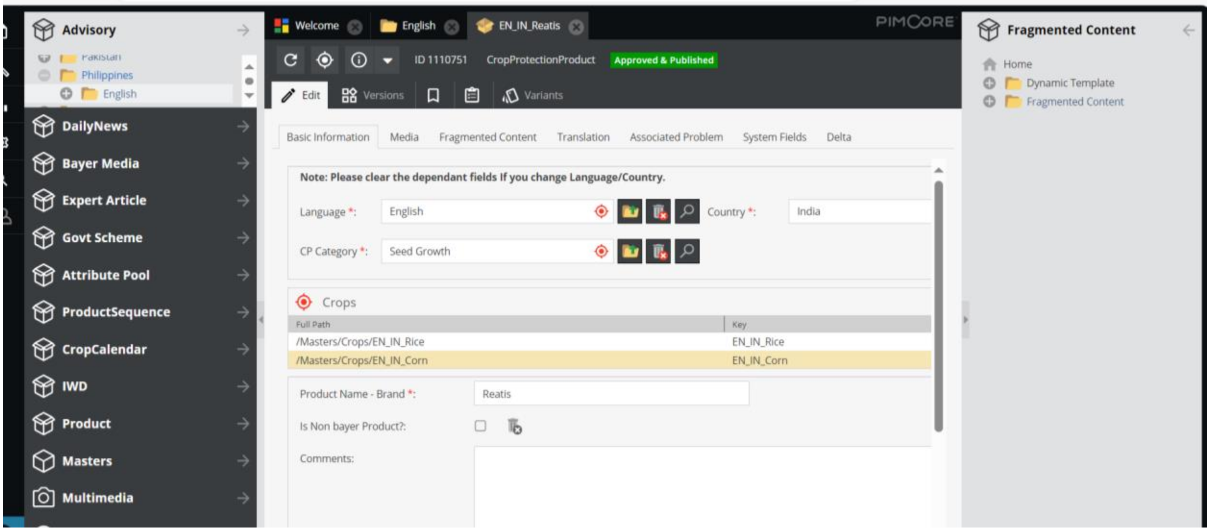
The company offers comfortable user interface with modules for Product Information Manager, Digital Experience Platform, Digital Commerce Framework, Master Data Management, Digital Asset Management, and Customer Data Platform (Pimcore, 2024).

Both the back-end IT configuration and infrastructure, and the front-end user interface (i.e. web-based or mobile app-based) are components in developing digital advisory. The back-end IT configuration can be applied across country with Application Programming Interface (API) functionality so that the information flows between or among two or more applications with the use of intermediary software.

The contents are created using a platform that are secured (Figure 5) and configured in the back-end structure (Figure 6). Computer science experts or IT engineers are responsible in the creation of content portal system.

Figure 5. *Secured and internet-based authentication of content developers used to access back-end configurations.*

Figure 6. *Example of back-end portal configurations used to encode digital advisory.*



Once the contents are encoded and uploaded, the information will be shown or reflected in the front-end user interface. The registration and authentication process (Figure 7) becomes mandatory in the user interface also to track the usage and/ or identity of the user. This front-end user interface can be web-based (Figure 8) or mobile application based (Figure 9) with API configuration. This process is very complex that requires numerous user testing and iterations.

Figure 7. *Example of registration and authentication of users accessing the digital advisories in web-based front-end customer interface or portal.*

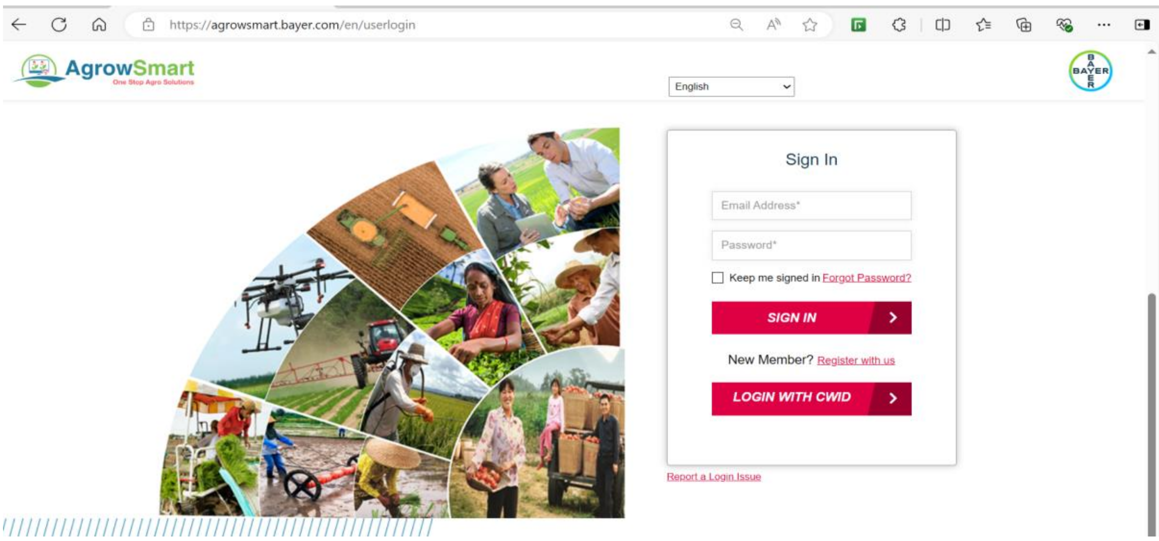


Figure 8. *Example of web-based front-end interface containing digital advisories.*

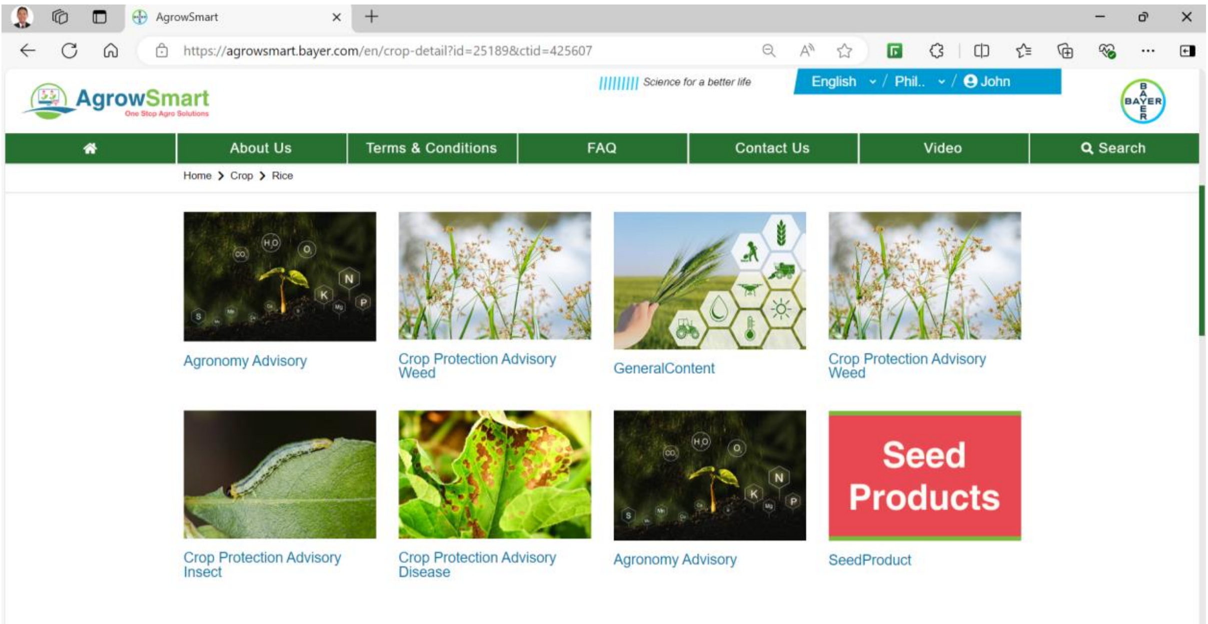
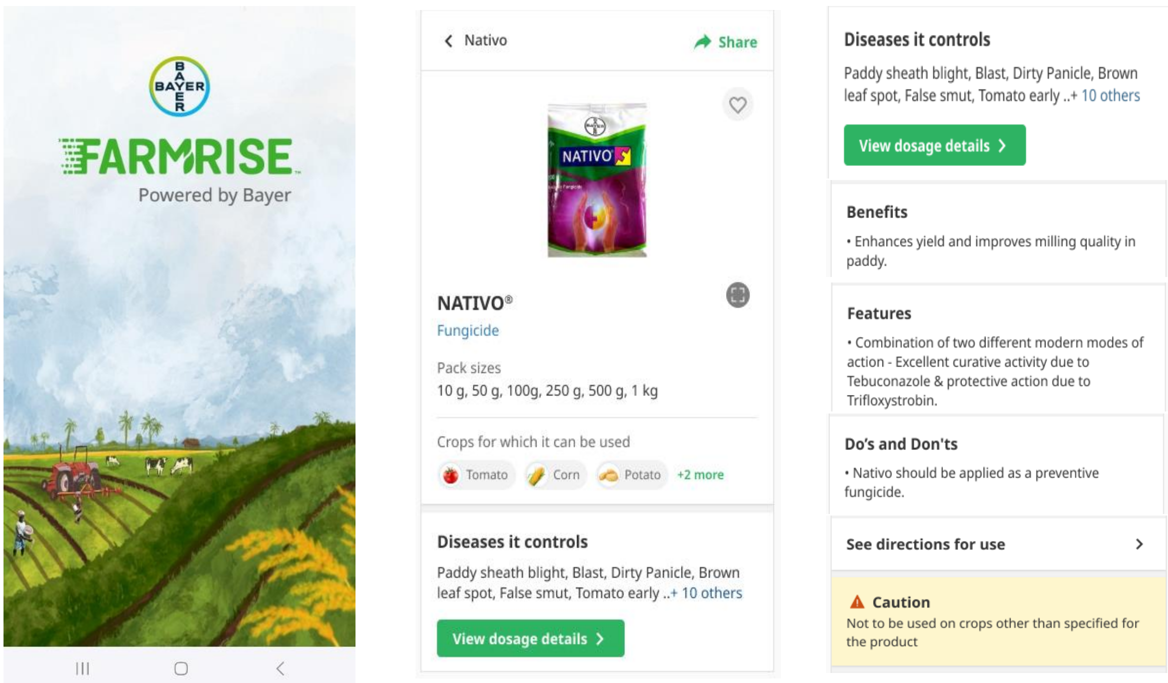


Figure 9. *Example of mobile app-based front-end interface containing digital advisories.*



There are also many IT companies in India, US, and Philippines offering creation of websites and mobile applications costing at least one thousand (US$

1,000) dollars. Some of these companies are Developer Bazaar Technologies, Konstant Infosolutions, Appinventiv, JLabs, White Widget, and Springboard Philippines (Clutch, 2024).

Some organizations also use existing and popular open-source digital platform. This can be a free and no code mobile applications like Google AppSheet, free social media platform such as Facebook, Instagram, and Tiktok, and free messaging platform such as Facebook messenger or WhatApp.

Sophisticated tools like 360 cameras are needed to develop contents that is compatible with Virtual Reality functionality. Such cameras are used to capture the setup of the actual field condition to ensure compatibility.

The content information may include weather information, financing or loans options, crop insurance options, pest problems, access to agronomy information, access to farm inputs, and access to commodity buyers or traders. The type of content will also impact the utilization of farmers based on platform to use. This can be in the form of text, but the more preferred type are infographics, short video, reels, sensors and AI applications with real time information from sensors (i.e. weather sensors, pest detection, farming recommendations).

Relevant and constant update of information is also preferred by the farmers. Popular platforms such as social media including Facebook are preferred by farmers rather than web based or digital mobile applications. The simplicity and easy to use features of social media platforms are the reasons for such popularity.

The creation and collaborative work of pandiscipline experts ranging from economist, crop agronomists, marketing, human resources (HR), IT professionals, and supply chain professionals is apparent. The economists focus on the strategy and ensure execution and success of the utilization of digital crop advisories. Crop agronomist focuses on the agronomy and technical information while marketing focuses on the communication message and delivery approaches.

Human resources support the manpower readiness with right skills to perform the tasks as well as development of soft skills like engagement techniques, mindset and behavioral changes. IT professional focus on the structural and infrastructure requirements of the digital advisories such as software, hardware, cloud hosting, and other IoT related needs. And lastly, the supply chain professionals aim to ensure availability and smooth movement of goods and services particularly in e-commerce related activities. As a summary, the relevant, accurate, and propriety digital advisory programs should consider different agents and processes such as leadership support, organization strategies, infrastructure, and communication messages and platforms.

Both linear and recursive communication system were apparent. Facebook social media digital advisories is more recursive having circular, causal, and feedback loop and interaction. However, most mobile applications where communication is linear from the developer to the intended stakeholders. Recursive system is more popular due to its interactiveness, mostly real time to the users like farmers.

The pandiscipline collaboration involving all disciplines are practiced more in profit-oriented private organizations or companies. Government organizations may or may have the continuity of the digital agronomy projects depending on the status of such. In some cases, project-based programs such as SpidTech mobile application loses its continuity due to changes in budgetary and cross organization/ team composition based on the Key Informant Interview conducted by the author. The enhancements of the functionality are compromised due to these factors making the digital advisories not appealing to farmers, thus losing their interest.

Some farmers have started creating Facebook pages either motivated to help other farmers, felt pride of having followers, or sometimes motivated by the income that can generated from creating video content. These types of digital advisories coming from farmer themselves had better influence and utilization of other farmers. Farmer experiences are perceived to be genuine and pragmatic by other farmers.

Infrastructure considerations include the cloud or IT web/ mobile applications hosting, mobile application development, compatibility to different types of smart phones (i.e. iOS or Android), and access of farmers to compatible smartphones, as well as Wi-Fi or mobile networks. During the developmental process of any digital advisory platform, User Acceptability Test (UAT) is performed. Selected and few respondents participates on this process to test the readiness and functionality of the platform like mobile applications. Infographics and user manual of the digital agronomy projects relating to its value and usage are developed by organizations to inform and guide the users. This is an important consideration before introducing digital mobile applications to the intended stakeholders, including farmers.

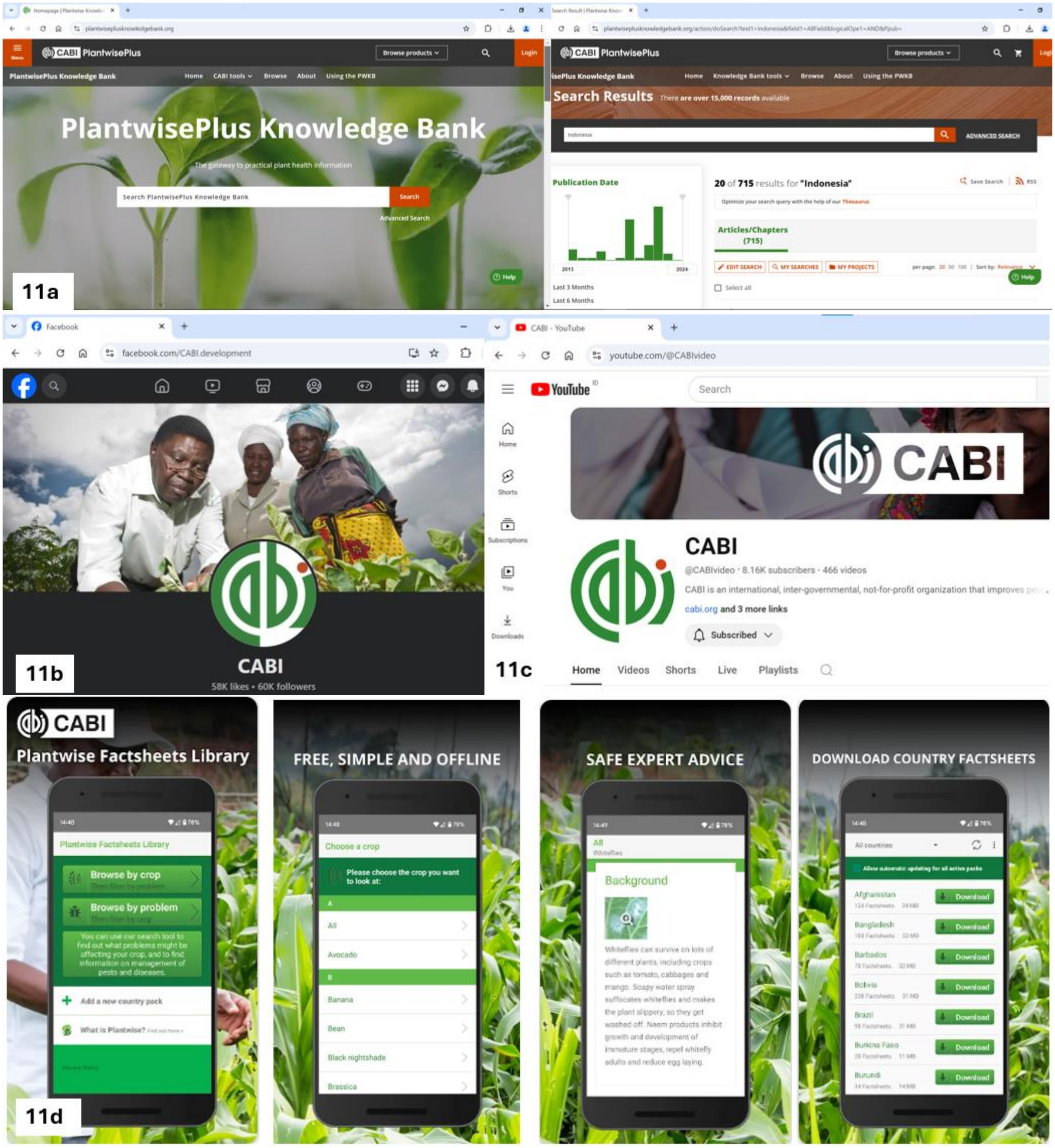
Digital crop advisories creators from different government and private organizations as well as various platforms of delivery available in the Philippines and Indonesia were evaluated based on desktop research, autoethnography, Focus Group Discussion (FGD), and Key Informant Interviews (KII).

Facebook and WhatsApp are the most common used digital platforms used by farmers in the Philippines and Indonesia (Figure 10). Facebook and its' messaging app Messenger are more prevalent in the Philippines while WhatsApp is more popular in Indonesia. Other free mobile applications such as YouTube, Tiktok, and Instagram are used in both countries. In addition, several public organization and company propriety agricultural mobile applications are available to farmers including the less popular and low access usage of websites.

Figure 10. *Common mobile applications with digital advisories in the Philippines and Indonesia.*

Centre for Agriculture and Bioscience International (CABI), an International not-for-profit organization also developed digital content for farmers globally including Philippines and Indonesia. The e-farming advisories are accessible through their website at https://plantwiseplusknowledgebank.org, mobile application' PlantwisePlus Factsheets, Facebook account https://www.facebook.com/CABI.development and YouTube https://www.youtube.com/user/CABIvideo (Figure 11) with the goal to improve people' lives by solving problem in agriculture and environment. CABI also used Twitter and LinkedIn as platforms for these e-farming advisories.

Figure 11. *Centre for Agriculture and Bioscience International (CABI) e-farming website (11a), Facebook (11b), YouTube (11c) & mobile application (11d) advisories.*



The utilization of different digital platforms varies across the different digital platforms. Facebook is the widely utilized platform with ~60,000 followers compared to Plantwise mobile application with ~10,000 downloads or YouTube with ~8,000 subscribers (Table 4). The identity of users of these e-farming advisories that cannot be determined poses a challenge in terms of reaching the desired stakeholder or end-user. These users, followers, or subscribers depending on the terminologies used in different digital platform can be a farmer, researcher, extension agent, or sales agent.

Table 4. *Not-for-Profit organizations digital advisories and mobile application platforms.*

No	Organization or Company	Classification	Crops	Digital platform	Reach, Users or Followers
1	Centre for Agriculture and Bioscience International (CABI)	Public	Rice, Corn, various	Facebook Plantwise mobile app YouTube	60,000+ 10,000 + 8,160+
2	International Rice Research Institute (IRRI)	Public	Rice	Facebook Rice Doctor mobile app YouTube	77,000+ 10,000 + 41,200+

The content in CABI includes a collection of digital advisory tools to support the decision making of agricultural advisors or extensionists. These include pest management guides, factsheets for farmers, technical factsheets, problem diagnoses, country resources, pest alerts, and language translation functionality (CABI, 2024).

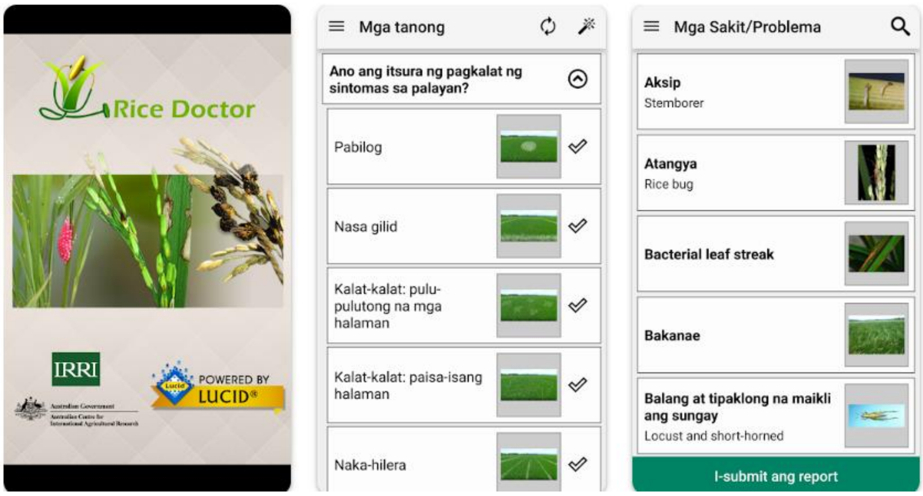
International Rice Research Institute (IRRI) is an international organization headquartered in the Philippines has mission to abolish poverty and hunger among people that depend on rice food systems (IRRI, 2024). IRRI utilizes digital technology transfer communications and e-farming advisories along with other related topics through their:

1. Website https://www.irri.org/
2. Rice Doctor mobile app – available in English and Tagalog (Figure 7)
3. Facebook at https://www.facebook.com/IRRI.Official
4. YouTube at https://www.youtube.com/@irrivideosofficial)

5. Twitter at https://x.com/irri, and
6. LinkedIn at https://www.linkedin.com/company/international-rice-research-institute/

IRRI also developed Rice Doctor mobile application (Figure 12). This is an interactive tool for extension workers, students, researchers and other users including farmers who want to learn, diagnose, and manage pest, disease, and other problems in rice field. This covers description, relevant information, and photos of more than 88 pests and diseases and other disorders. The combination of photos and text descriptions aids farmers to diagnose and manage their problems. The keyword search functionality enables users to directly access specific topic or problem or interest.

Figure 12. *International Rice Research Institute Rice doctor mobile application.*



Rice Doctor mobile application developed in 2016 or eight (8) years ago, but the utilization is still low about 10,000 (Table 4) or less than 1% relative to 15 million rice farmers in the Philippines and Indonesia - 2.9 million farmers in Philippines (Philippine Rice Research Institute, 2019) and 13.1 million farmers in Indonesia (Mardiharini, et al. 2023).

In the Philippines, several key government agencies and private companies developed digital farming advisories on the web or internet, contact center, social media, and mobile applications designed specific for the country (Table 5). Among the public organizations include Philippine Rice Research Institute, Department of Agriculture, Department of Science Technology- Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD). The Department of Agriculture – Agriculture Training Institute provides various online courses through its website at https://elearn.e-extension.gov.ph/ and contact center (Figure 13) (DA ATI, 2023). For private and profit companies, two large multinational seeds and pesticide companies that include Syngenta and Bayer Crop Science and one multinational fertilizer company were active in knowledge transfers of digital advisories and e-commerce.

Figure 13. *Contact Center services of the Department of Agriculture - Agricultural Training Institute.*

Facebook is also the prevalent digital platforms used in the Philippines (Table 5). Syngenta Facebook page recorded the highest number of utilizations with more than 2 million followers. YouTube, Tiktok and Instagram social media platforms were also used. Findings show that farmers prefer to use mobile applications like Facebook instead of propriety mobile application advisories.

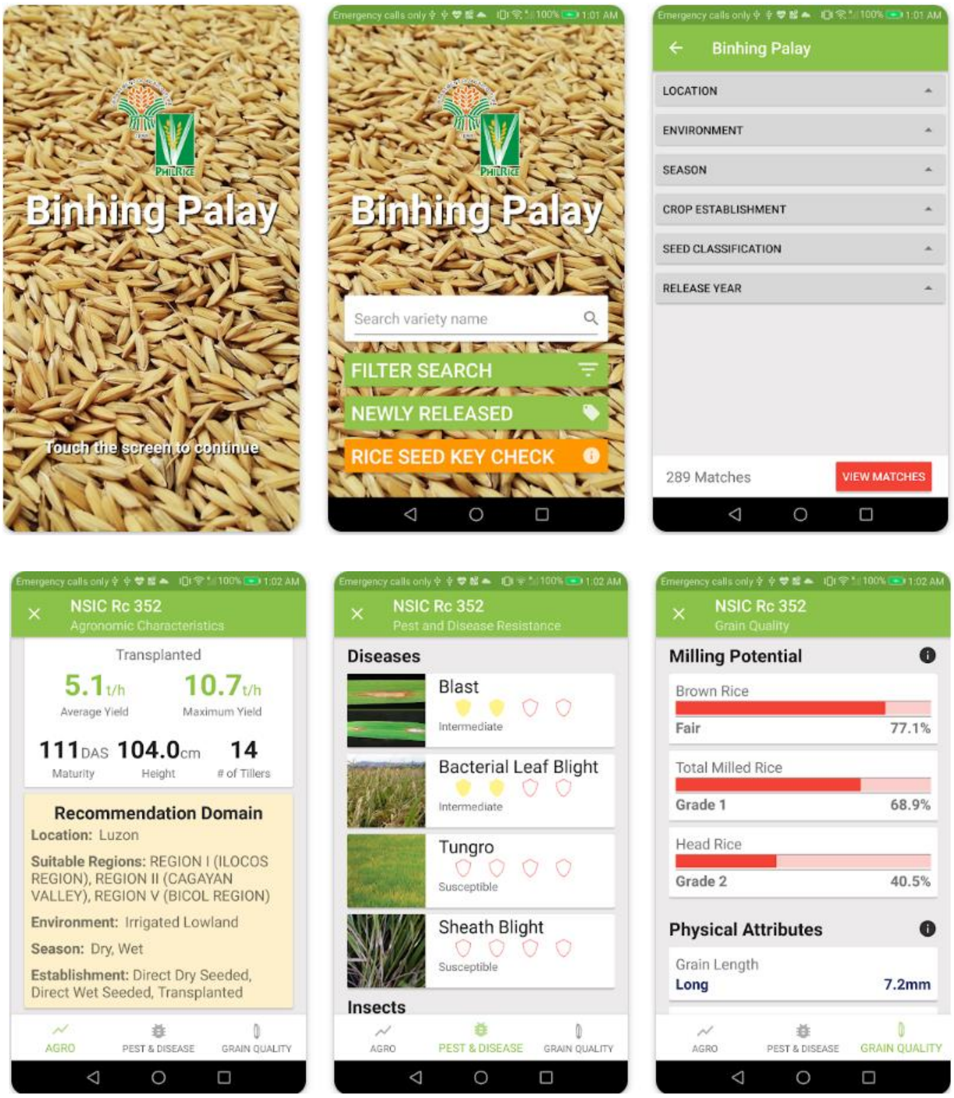
Philippine Rice Research Institute developed Binhing Palay and eDamuhan mobile applications in 2018 and AgriDoc in 2015 to leverage digital advancements in communication. After about 6 to 9 years from development of these e-farming mobile applications advisories, there is still a gap or last mile challenges due to its' low utilization despite offline its' functionality or not requiring internet or Wi-Fi connectivity once it is downloaded in the mobile smartphone.

Table 5. *Organizations with digital advisories and mobile application platform available to farmers in the Philippines.*

No	Organization or Company	Classification	Crops	Digital platform	Reach, Users or Followers
1	Philippine Rice Research Institute	Public	Rice	Facebook Binhing Palay, eDamuhan AgriDoc mobile app	2,200+ 50,000+ 10,000 + 5,000 +
2	Department of Agriculture	Public	Various	Facebook Fertilizer Calculator app Online, contact center	375,000+ 1,000 +
3	Department of Science Technology-(PCAARRD)	Public	Various	Facebook SpidTech mobile app	204,000+ 10,000 +
4	Atlas	Private	Rice, Corn	Facebook Fertilizer Expert mobile app	18,000+ 1,000 +
5	Bayer Crop Science	Private	Rice, Corn	Facebook Adviser Program mobile app	116,000+ 1,000 +
6	Syngenta	Private	Rice, Corn	Facebook Tiwala Grower mobile app	2,000,000+ 5,000 +

The Binhing Palay mobile app (Figure 14) provides information and search function on the different rice varieties and quality that aims to help the farmer choose the appropriate variety in specific cropping practices, location, and season. Binhing Palay has a catalog of released rice varieties in the Philippines that help farmers decide the best variety for the season. The list of rice varieties can be sorted and filtered according to location, environment, season, crop establishment, seed classification, and release year.

Figure 14. *Philippine Rice Research Institute Binhing Palay mobile application digital advisory.*



Binhing Palay also features the characteristics of each variety, which include the full descriptions of its' maximum and average yields, maturity, height, number of tillers, pest and disease resistance, milling potential, physical attributes, and physicochemical characteristics. It also features rice seed key check from PalayCheck information to guide the farmer in choosing and using quality seeds to get the maximum yield.

eDamuhan (Figure 15), launched in 2018 is another mobile application advisory with search tab functionality focused on weed information including scientific and local names, weed description, impacts to rice crop, and recommended management to combat the weed problems in the rice field. It uses the latest artificial intelligence technology to process and recognize the images of the different weed species. Currently, the weed recognition feature can recognize 22 weed species. It is continuously being tested and improved to recognize more species of weeds and improve the functionalities that it can offer to users.

AgriDoc (Figure 16), is another mobile application developed by Philippine Rice Research Institute. This offers digital advisory to help farmers on record keeping, task scheduling, geographical visualization, making informed decisions,

- **Simple Record Keeping.** Farmers can keep the information on the activities and expenses in the farm and categorize them to major farming operations.
- **Easy Task Scheduling.** Farmers can plan their tasks and get reminders or notifications of their activities in a calendar view.
- **Geographical Visualization.** Farmer can view, indicate lot boundaries, and create tags or names of their farms through satellite images provided by Google Maps for easy identification.

- **Make informed decisions.** Farmer can access information and knowledge on comprehensive released rice varieties and growing and managing their rice crop properly to get high yields. It also features Rice Crop Insights that allows farmer to prioritize the needs and concerns of rice plants in specific growth stage.

Figure 15. *Philippine Rice Research Institute eDamuhan mobile application digital advisory.*

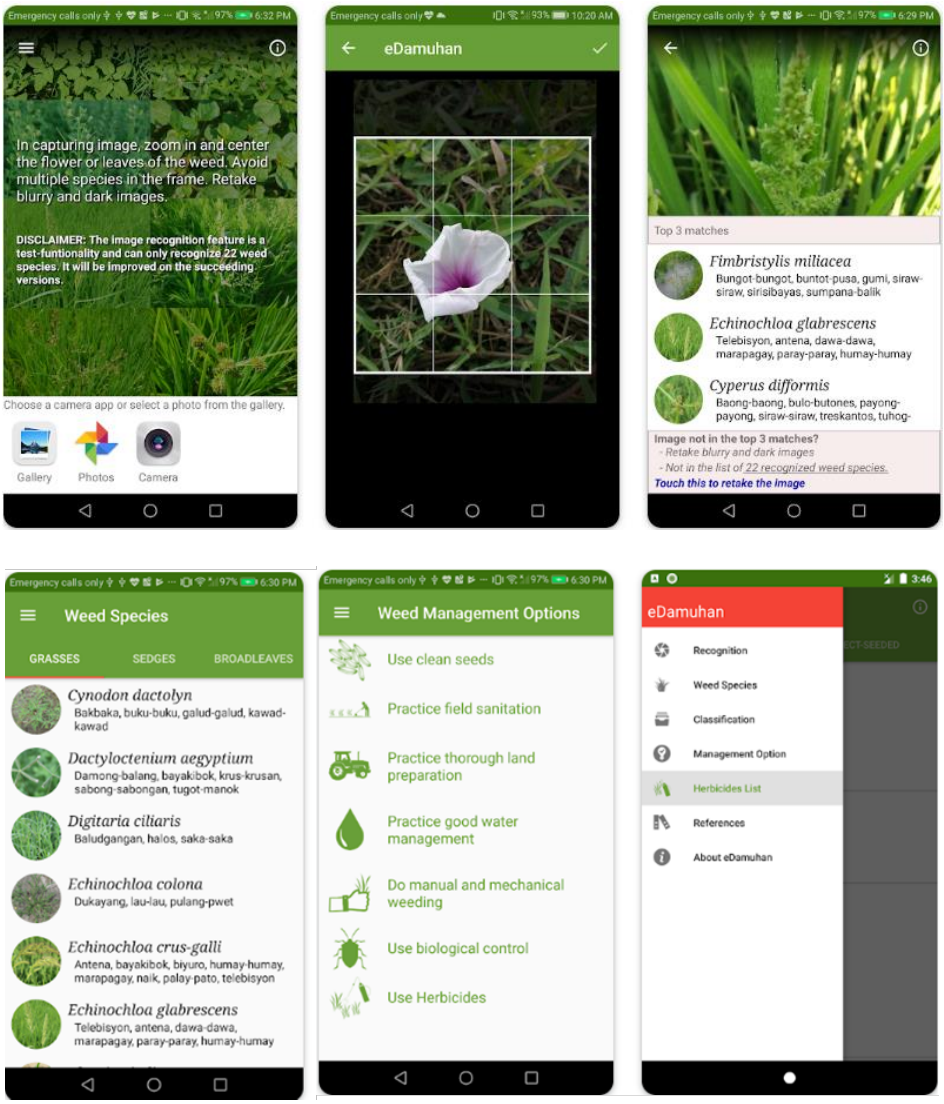


Figure 16. *Philippine Rice Research Institute AgriDoc mobile application digital advisory.*

Private companies such as Atlas, Bayer Crop Science, and Syngenta had higher usage of their respective Facebook Page rather than mobile application. However, the content focuses and put emphasis on communication of product promotions rather than crop advisories. Social information creates impression to farmers that these companies are dominating product campaigns aimed at their profit and economical advantage rather than helping to improve the profit of the farmers.

Recently, Bayer Crop Science also utilized advanced technological tools such as Virtual Reality (VR), Augmented Reality (AR), and Gamification with associated prizes, gift or coupons as upon completion of each module in disseminating farming advisories (Bayer, 2022). These tools are very interactive and immersive making the learning experience engaging and motivating.

The Virtual Reality (Figure 17) featured new and high yielding corn seed hybrid that offers built-in protection against destructive insect pest throughout the growing season. It uses a Virtual Reality glass to have immersive and 3D viewing like the actual field conditions. The Augmented Reality (Figure 18) featured how to identify and manage one of the major insect pests in rice. With AR mobile app, the created contents are superimposed or seen in the actual background of the surrounding. And lastly, the gamification (Figure 19) featured how to manage the weed problems of farmers economically and effectively in the rice field. It is mobile and internet-based application that allows users to play, which can include select and drag functions.

Figure 17. *Virtual Reality technology used for corn seed and agronomy knowledge transfers.*

Figure 18. *Augmented Reality technology on insecticide product used to manage rice pest.*

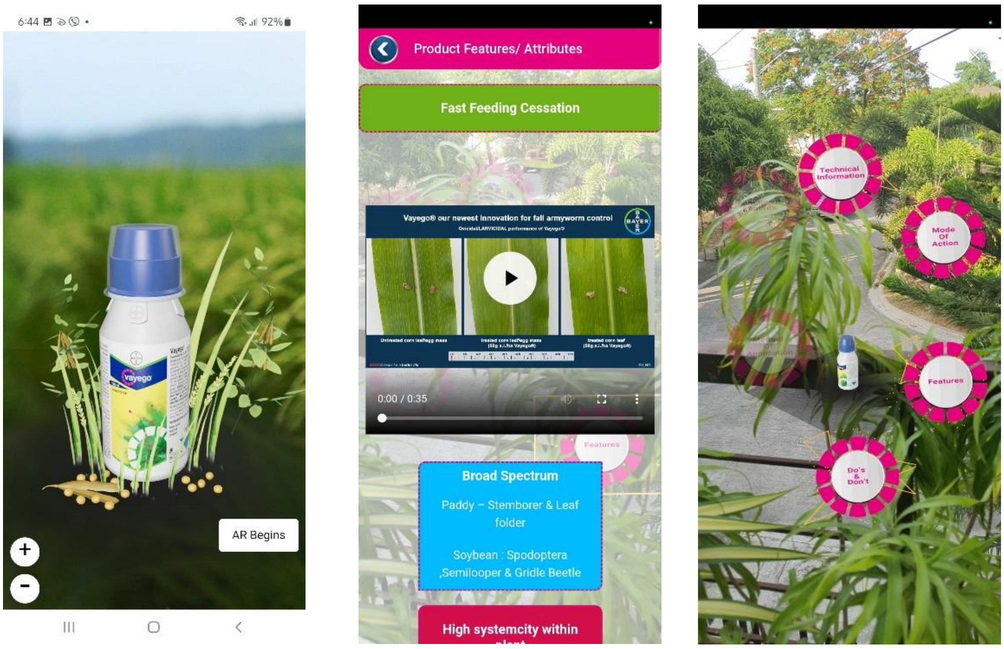


Figure 19. *Gamification platform in mobile about weed management in rice.*

In the case of Indonesia, the common mobile application platforms utilized in the field of agriculture is focused on farming advisor, soil test services, farm input marketplace, financing, and direct connection of farmers to market such as Semaai, TaniHub, Sayurbox, Eden Farm, and IGrow (Humana, 2024 and InvestinAsia, 2024). Despite these available mobile applications, findings show that farmers prefer to use the mobile applications like WhatsApp for communication as replacement of mobile phone calls and are not maximized for getting or accessing the crop advisories information. However, the utilization of mobile applications on digital cropping advisories in Indonesia is also low (Table 6). Although, some mobile applications like Yara fertilizer expert app and Sayurbox had reached millions downloads already.

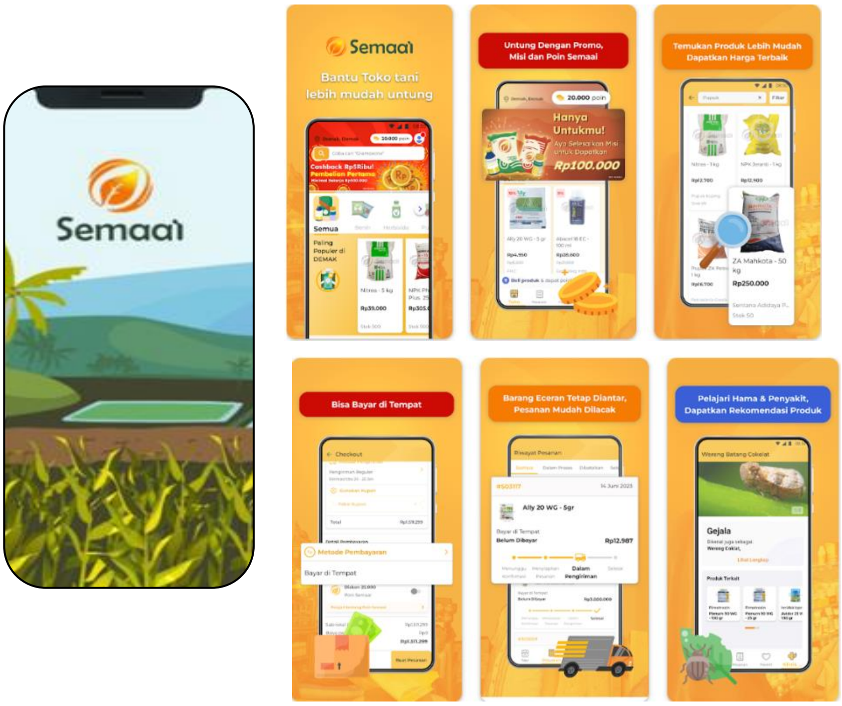
Table 6. *Organizations with digital advisories and mobile application platform available to farmers in Indonesia.*

No	Organization or Company	Classification	Crops	Digital tool(s)	Reach, Users or Followers
1	Semaai	Private	Various	Semaai mobile app Facebook Instagram	10,000+ 220+ 820+
2	TaniHub Food Solutions	Private	Various	Instagram	141,000+
3	Sayurbox	Private	Various	Facebook Mobile app Instagram	32,000+ 1,000,000+ 526,000+
4	EdenFarm	Private	Various	Facebook	204,000+
5	Yara	Private	Various	Facebook Fertilizer Expert	181,000+ 5,000,000 +
6	Bayer Crop Science Indonesia	Private	Various	Facebook Instagram	286,000+ 5,000+
7	Syngenta Indonesia	Private	Various	Facebook Instagram	528,000+ 18,000+

Semaai mobile application is a diversified technology-based e-commerce and advisory services for farmers covering more than 4,000 villages. It is available in the Android platform. The application is intended for farmers to access more than 8,000 products or SKUs from 110 suppliers of agricultural input, to get farming advisories, and to conduct soil test services. The platform offers farmers ease and options to select and purchase seeds, fertilizers, pesticides, and tools to their farms.

Semaai features digital agronomy advisories, marketplace of agricultural products, financing services, and agribusiness services such as access to market, inventory management, demand creation, and logistics. The agronomic advisory provides information on more than 100 different pests and their management. It also provides a listing of different pesticides recommended to control specific pest effectively.

Figure 20. *Semaai digital agronomic advisories, agricultural product marketplace, financing, and other agribusiness services.*

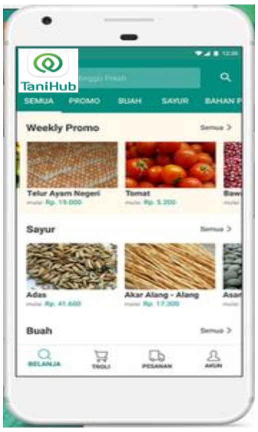


TaniHub (Figure 21) is mobile application connecting farmers closer to people or consumers. Farmers benefit from getting fair price of their produce due to reduction of long distribution chains. It is business to business (B2B) e-commerce marketplace for agricultural produce or farmer harvested products, currently focused on fruits and vegetables now.

Through Tanihub app, farmers can sell their products easily through this mobile application matching with the buyers. As a result, consumers get the fresh harvests from the farmer. With this value chain innovation, the price and supply of fresh produce becomes stable, thus supporting government as well. The mobile application features easy and faster search of products, ease in selling farmer harvest, and special offers and promotions through discounts and price cut vouchers.

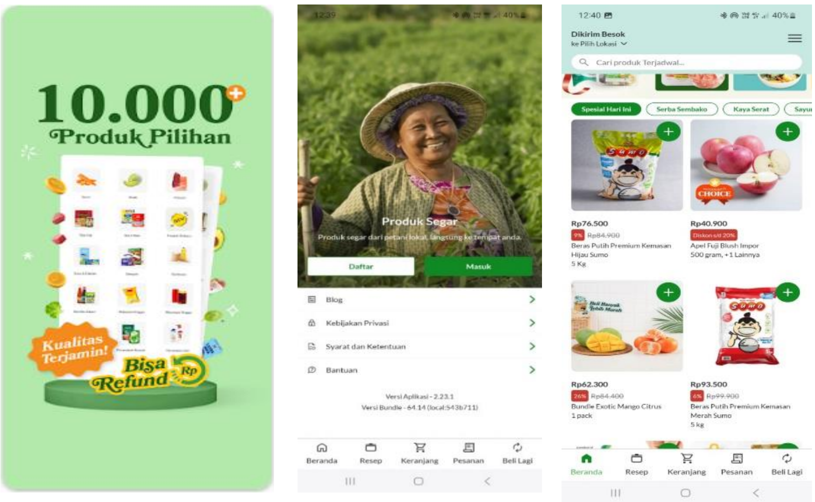
Currently, TaniHub has partnership with thirty (30) large retail companies connecting 15,000 farmers from Lampung, South Sumatra to Central Java. With this mobile app, farmers can have freedom to choose their market and avoid wastage of their produce, thus creating social and environmental benefit. Farmers also can sell their products in huge number and get a competitive price from supermarket improving their farm income.

Figure 21. *TaniHub Food Solutions B2B e-commerce marketplace for agricultural farm produce.*



Sayurbox (Figure 22) is another e-commerce mobile application that features sale and distribution of fresh and high-quality farm produce directly from farmers to the consumers. It has search functionality so that consumers can choose and select from wide variety of fresh products. The selection for organic and pesticide-free farm produce is also available. This mobile app also provides the information of the farmer who grow the products. With Sayurbox platform, it helps farmers to plan their production efficiently specially the harvest time. As a result, farmer can secure better and more stable prices of their harvested produce.

Figure 22. *Sayurbox e-commerce direct sourcing from farmers.*



EdenFarm (Figure 23) is a mobile application used for simplifying B2B supply chain farm produce by reducing the layer or middleman. As a result, farmers can sell their produce at competitive prices through this app. EdenFarm provides purchase the harvest of farmers directly, provides warehousing, and then sell to restaurants, cafes, open markets, and ships. EdenFarm partnered with Telkomsel telecommunications to provide advisories and insights of precision farming technologies to farmers.

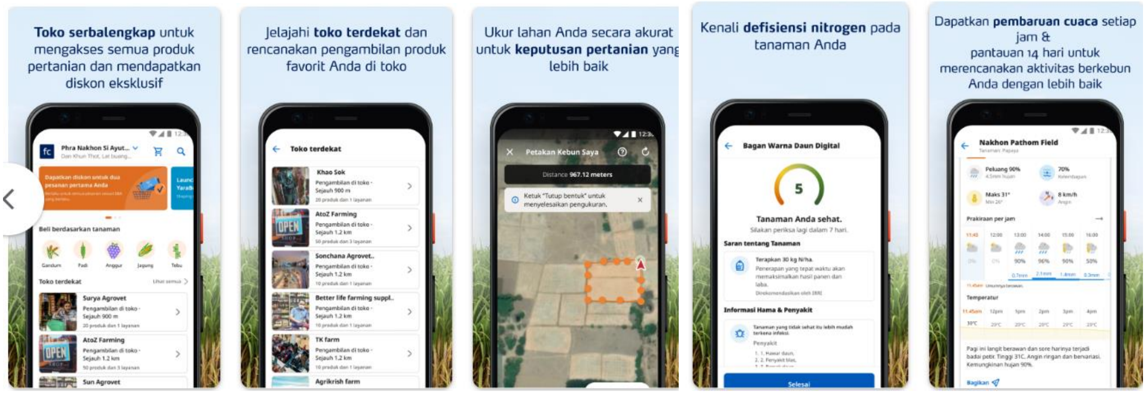
Figure 23. *EdenFarm business to business (B2B) supply chain directly sourced from farmer to consumers.*

Yara FarmCare mobile app can help farmers to have access and buy fertilizer and provides advises about easy and effective fertilizer application to achieve higher yields at lower costs (Figure 24). It has several features:

1. Farm map. This tool can delineate the boundaries of the farm, which allows accurate measurement and fertilizer recommendation to achieve optimal crop growth.
2. Fertilizer calculator. This allows calculation of precise amount and type of fertilizer needed to maximize crop growth and farm income.
3. E-commerce shop. Farmer can find, order, and buy Yara products using the mobile application.
4. Weather forecast. Provides farmers with local weather forecasts and advisories to plan their farming decisions better. This allows farmers to have confidence on the right timing for sowing, fertilizing, and other critical activities for optimum crop growth.

   Specifically, this mobile app provides timely advice on when and how to spread and spray fertilizers effectively based on your location, soil type, and hyperlocal weather conditions.
5. Digital Leaf Color Chart (DLCC) guide: This helps farmer make informed decisions about fertilization for optimal growth and maximized yields. The mobile app analyzes the nitrogen levels and assist farmers to time nitrogen application properly based on the comparison of the leaf color on the field and the color panel of the DLCC tool.

Figure 24. *Yara fertilizer advisories and e-commerce mobile application to help farmer optimize crop yields.*



As a summary, the findings based on desktop research shows that farmers in both Philippines and Indonesia still have limited information, access, understanding, and utilization of digital advisories. The rice and corn farmers in the major growing areas that were randomly interviewed in the study had utilized the social media apps like Facebook and Instagram on their smartphones but not did not have the company propriety mobile application crop advisories based on desktop research (Tables, 5, 5, and 6). However, farmers accessing the free social media applications have limited information on crop advisories but rather mostly on any trending or popular topics not necessarily related to e-farming advisories.

Several concerns also affecting the low utilization particularly on mobile applications such as issues of installing and navigating the mobile app, crashing or non-functioning of the mobile app, not relevant information, not engaging content, and no additional benefit to farmers. Non-functioning or error encountered when accessing mobile apps is frustrating to users or farmers. This issue could be due to the versions of the mobile app that needs updating, compatibility of the operating system, or other IT related issues that should be avoided to ensure seamless user experience.

Results also showed that majority of farmers get the information from fellow farmers, farmer groups, or farmer cooperatives (Figure 25). In Indonesia, farmer groups are active in sharing farming advisories because they are member of such groups which is used by the government to utilize government subsidy programs such as fertilizer. Similar situation in the Philippines was apparent where cooperatives and farmer groups get government funding and subsidies through their respective cooperatives. Face to face and traditional interaction among farmers is still the most preferred and major source of farming advisories. In Indonesia, farmer group in village is common where government programs such as fertilizer and seeds subsidies are channeled.

In addition to farmers or farmer groups, the other sources of crop advisories include store, retailers, or financiers where they purchase or take loans of their farm inputs. Government including local government extension agents as well as private companies were also identified as sources of information.

There is also indication of the increase usage of digital media particularly social media platforms such as Facebook. Although, the use of organizations propriety mobile crop advisory applications is still low (Table 5 and Table 6).

Figure 25. *Sources of crop advisories among farmers.*

On Content or Information Themes

Based on autoethnography, focus group discussion (FGD), farmer interviews, and key informant interviews (KII), the responses of farmers related to their needs were classified based on inductive codes, themes and subthemes (Table 7). The common information needed by farmers include weather, financing or loans, pest problems, access to agronomy information, access to farm inputs, and access to commodity buyers or traders.

Table 7. *Farmer digital advisory needs classified into different qualitative research codes, themes, and subthemes.*

No	Codes	Theme	Subthemes
1	Weather risk	Farmer productivity and profitability Crop insurance	Unfavorable condition typhoon/ La Nina and drought El Nino. Cannot pay loans of farm expenses. Insurance need due to calamities. Philippine government provide certain amount of crop insurance.
2	High farming expenses	Access to credit Subsidy of inputs (i.e. fertilizers, seeds)	Lack of affordable financial institutions. Access to financing with lower interest rate. Government subsidies on seeds and fertilizers in Philippines and Indonesia.
3	Pest problems	Different weeds, insect pests, and diseases reduces crop yield and quality.	Weeds competes nutrition with crops. Insect pests and diseases causes crop damage.
4	Access to agronomy information	Limited reach of information, mostly coming from other farmers, government extension agents, and private companies.	Easy and understandable agronomic advises. Relevant and useful to farming.
5	Access to farm inputs in stores	Limited farm inputs in store	Available farm inputs like desired seeds, fertilizers, and pesticides.

6	Access to trader or commodity buyer	Forced to sell harvested product to financier or loan provider who provided the loans	Cannot choose trader or commodity buyer with higher commodity price. Middlemen buyers lower the commodity price instead of direct to millers or customers.

Farmers are more concerned about the risks in farming and high finance charge of their loans or borrowed money instead of agronomic advice. Financing options and lower risk in farming like provision of insurance to improve income should be incorporated in the digital tool being developed by any public or public organization. Funding support should be available for these identified pain points or needs of farmers not just on the agronomic advisories.

Farmers get their farming advisories from fellow farmers, public extension agents, and company representatives to improve their crop productivity and income. However, they are not hesitant to use digital tools due to affordability of smartphones, limited access to internet, and additional efforts needed to learn the digital platforms. Although, few farmers showed high interest or has been utilizing social media or mobile applications (i.e. Facebook, WhatsApp). Farmers also indicated that their children taught them to use social media and mobile applications.

Farmer have provided several insights on how to drive adoption and utilization of digital advisories. Findings show that farmer-to-farmer crop advisory sharing is the most preferred and most influential approach in disseminating information. This can either be face to face even digital approach. In the Philippines, the Department of Agriculture have extension program using farmers to provide cropping advisories to fellow farmers called Farmer Led Extension (FLE) or Farmer Field School (FFS). Leveraging key farmer influencers, cooperatives, and non-profit municipal agriculturist, technicians, and extension agents can help boost usage of digital advisories (Mohamood et al., 2017, Qamar, 2012, and Tiraieyari et al., 2010). In addition, the children of the farmers who are technology savvy can bridge the digital gap among farmers.

Agents and Its Complex Systems on Digital Advisories on Content Information Creation and Delivery

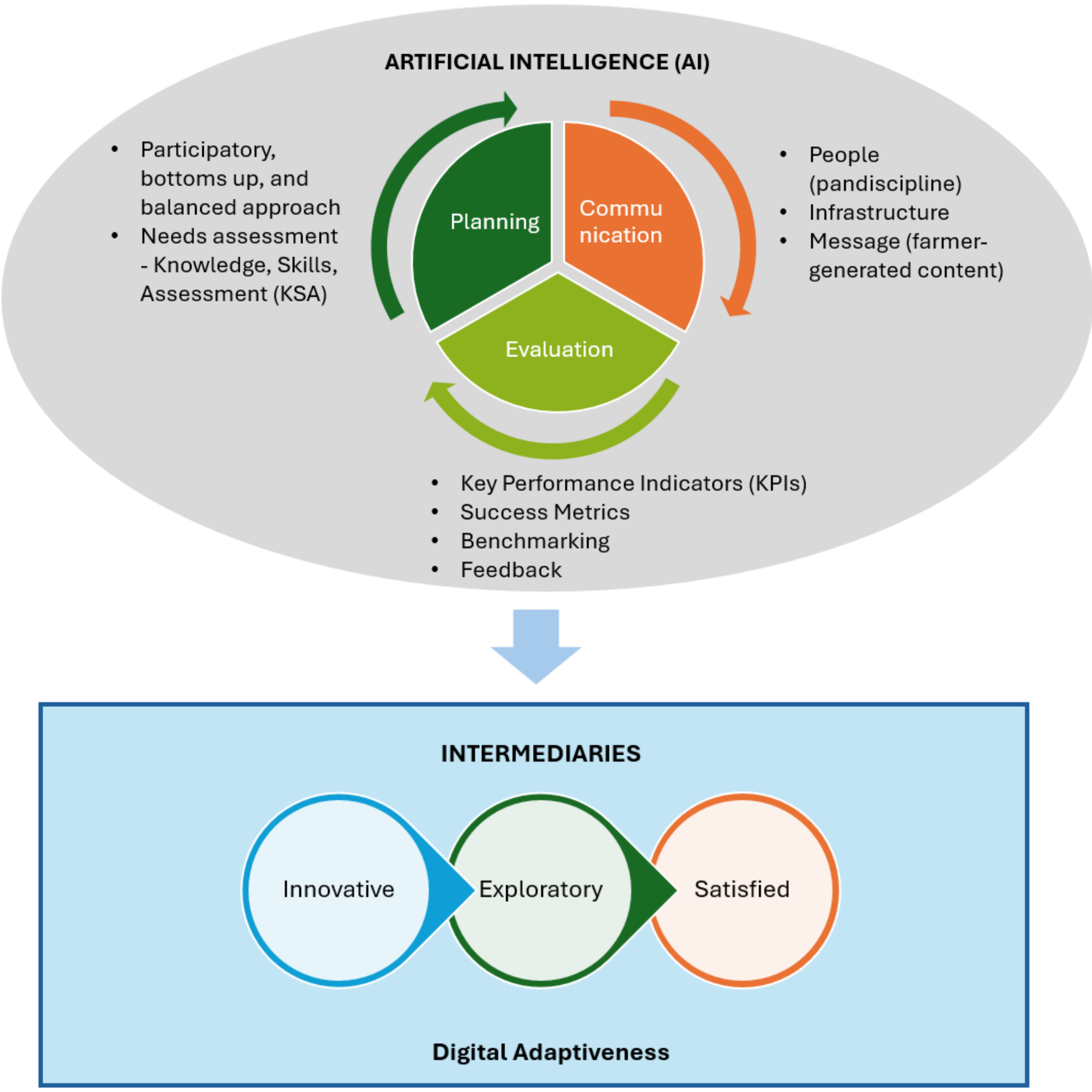
There are several and complex agents interacting in the e-farming knowledge transfer ecosystem having a dynamic process. These agents can be living (biotic) and non-living (abiotic) adapting in the complex system by exchanging matter, energy, or information.

Living or biotic agents can include pandiscipline of organizations or people within the organization. These are organizations or companies creating, communicating, monitoring, and evaluating the impact of the e-farming information or content, Information Technology (IT) organizations, telecommunications company, organizations who are owners/ developers of communication platforms, capitalist, businessmen or financiers, commodity traders, government regulators, intermediary agents (extension agents, retailers or stores, farmer children or relatives), and the farmers themselves as the end users. In addition to people and organization, biotic factors that can affect the success or failure of crop production include pests and diseases.

Non-living or abiotic agents include IT or internet infrastructures and its signals, hardware and software, platforms used in communication, content types, as well as weather affecting the crops of the farmers.

Findings revealed that creation of digital content advisories is made of several agents interacting in the complex system but organized in key process. Based on autoethnography and interviews, the PCE (Planning-Communication-Evaluation) model was developed and proposed as a guide in developing e-farming advisories to different personas with varying levels of digital adaptiveness (Figure 26). Digital adaptiveness among farmers can be improved with the aid of intermediary agents and appropriate prioritization or prospecting of innovative farmer personas. Moreover, Artificial Intelligence applications can also play an important agent in the PCE model to improve efficiency of different processes.

Figure 26. *E-farming system guide to ensure success of digital crop advisories.*



The PCE processes or model is composed of the E- Knowledge Management complex system, which is proposed and theorized in this dissertation. **Planning (P)** is the first step of the process, which involves design building, wireframing, user interface (UI), and user experience (UX). **Communication (C)** or E- Knowledge Transfer, the second step which involves the flow or exchanges of digital information. And lastly, **Evaluation (E),** which refers to the monitoring and assessment of the effectiveness or success of the digital initiatives such as crop advisories.

In the **Planning** phase, relevant stakeholders are involved in a participatory, bottoms-up, and balanced approach in identifying the needs, design, and desired outcome. This can be achieved by understanding the gaps relating to Knowledge, Attitudes, Skills, and Aspirations (KASA) (Bennett, 1979) and by developing blueprint of the digital design or wireframing.

Wireframing involves the creation of a basic visual representation of a website or mobile application. Wireframing is a crucial step in the design process of websites, apps, and other digital products. It involves creating a visual representation of the layout and structure of a digital interface, often using low-fidelity tools like pen and paper or simple digital software such as Adobe and Sketch including AI functionalities. There are several benefits of wireframing:

- Early-stage decision-making: It helps identify potential issues and make informed decisions about layout, navigation, and user flow.
- Improved communication: Wireframes provide a shared understanding of the design concept among stakeholders.
- Reduced development time: By clarifying the structure early on, wireframes can streamline the development process.

- Enhanced user experience: Wireframes help ensure that the interface is intuitive and easy to use.

There are key characteristics of wireframes. First, it focuses on the structure, wherein wireframes prioritize the arrangement of elements, such as buttons, text fields, images, and navigation menus. These elements are representation of the symbolic interactionism in communication under cybernetic tradition. Second, wireframe has fidelity design aspect, wherein color, typography, and detailed graphics are considered. And the third and last characteristics, iterative wherein wireframes are often revised and refined based on feedback and testing. Complexity theory plays into action in the process of wireframing given the adaptive nature of the design and redesigning.

Based on the interview from content developers, there are key stages in the designing or wireframing process:

1. Identification: Identifying the knowledge that needs to be transferred and the mindset or attitude that needs to be changed. This includes identifying the information, skills, expertise, and attitudes that are critical to the organization's success. In the study, most farmers are not interested to use digital crop advisories due to its nature and limitations.

2. Capture: Capturing and documenting the identified knowledge and attitudes. This can be done through various methods, such as creating materials such as information, infographics, videos, and other interactive innovations such as Virtual Reality, Augmented Reality, and gamification (Figures 17, 18 & 19). Currently, there are available AI tools that can be used to create contents in local language and captivating videos.

3. Organization: Organizing the captured knowledge into a structured format that is easily accessible and understandable. This involves creating knowledge repositories, databases, or digital learning platforms such as use of Facebook and Instagram and company priority mobile application (Tables 4, 5 & 6).

The second step on the system is the **Communication (C)** or E- Knowledge Transfer, which involves the systematic sharing and dissemination of information and expertise in digital environments. It's essential for organizations to effectively transfer knowledge to ensure continuity, innovation, and adaptation to changing circumstances, a feature in Complexity theory. Dissemination and understanding are crucial in this process. However, there are many factors and recursive communications that are interrelated with content creation (organizations) and audience (farmers) affecting the whole process of learning.

1. Dissemination: Distributing the knowledge to the intended audience or farmer. This can be done through various channels such as websites, social media, and company mobile applications.

2. Absorption: Ensuring that the knowledge is understood and applied by the recipients. This may involve providing opportunities for practice, feedback, and support.

Evaluation (E), the last step in the complex system is the assessment of the effectiveness of the knowledge transfer process. This can be done through performance metrics (i.e. Key Performance Indictors), surveys, and interviews. Impact evaluation of digital content aims to assess the extent to which the content has achieved its intended goals. It's a crucial step in understanding the effectiveness of digital initiatives, i.e. mobile applications, social media, or website. The impact can be on reach, knowledge gain, skills developed, and attributes changed.

There are examples of metrics that can be used to evaluate the impact of the e-farming knowledge transfer. Based on the desktop research, the performance metrics were based on the number of downloads for mobile applications or number of followers in social media. However, the following metrics can also be utilized.

- Farmer satisfaction: Assessing farmer satisfaction with the knowledge transfer process and materials.
- Usage rate, Completion rate, Click-through rate, or Engagement rate: Tracking the percentage of farmers who access or complete the knowledge transfer program. Tracking how long users spend on different pages or sections of the content. Measuring the number of clicks on links or calls to action within the content. Assessing the level of engagement with the content on social media platforms.
- Time to proficiency: Measuring how long it takes farmers to become proficient in the new knowledge or skills
- Knowledge retention: Measuring how well farmers retain the information after the transfer.
- Knowledge application: Assessing farmers' ability to apply the knowledge in their work or daily life.
- Return on investment (ROI): Calculating the economic or desired benefits of the knowledge transfer process, especially for profit-oriented companies and organizations' funding or sustainability, respectively.

Key Performance Indicators (KPIs) and Benchmarking are also commonly used for metrics evaluation. Key Performance Indicators are specific metrics that are used to measure the performance of an organization, department, or project. For instance, organizations or companies would set and assessment the number of farmers reached and downloaded the mobile e-farming application. On the other hand, benchmarking involves comparing an organization's performance to industry standards or competitors. For instance, the comparison of the number of followers in Facebook page between the two multinational agricultural companies Bayer and Syngenta.

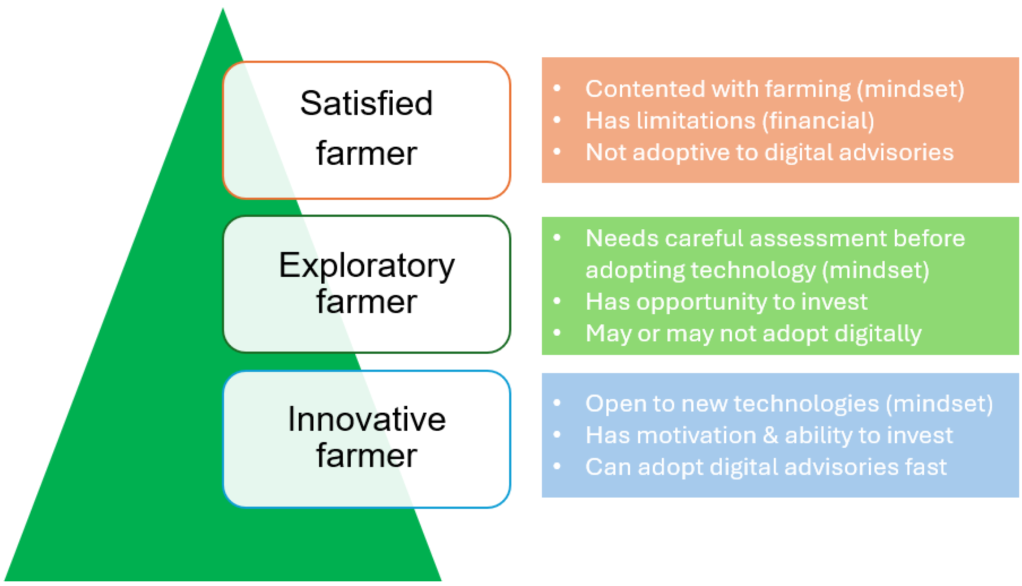
The success factors of digital agronomies can be measured based on organization goals. The improvement in knowledge, attitudes, skills and aspirations (KASA) is a good parameter to measure (Bennett, 1979). This can be achieved when there is high utilization and repeat usage of the advisories which is the result of the improvement of skills and change of farmer attitude. Practicing such changes contributes to the realization of ultimate end result of any e-farming communication.

Research Question 2. Why social information and how Complexity Theory in communication can be theorized and be developed into constructs to change the mindset and behavior of aging farmers and to engage new generation farmers through digital interventions?

Research findings show that understanding the motivation and social information of farmers is important to influence understanding and utilization of digital advisories. There are two concepts that can drive adoption and change the mindset and behavior of farmers. The first concept is the farmer classification using "**early adopters"** in relation to ability to use and drive digital crop advisories (Figure 27). The other concept is leveraging "**intermediaries**" that include children, relative, or family member of the farmer that has interest and knowledge on digital technologies.

Research findings showed that farmers can be categorized into three different personas – *Innovative farmers, Exploratory farmers, and Satisfied farmers*. Innovative farmers tend to embrace new technologies farmers such as modern farm machineries and digital innovations. They are usually financially capable and can buy and utilize the use smartphones in their farm operations. Few farmer respondents are using latest models of smartphones similar with other population in big cities.

Figure 27. *Categorization of farmer personas relative to digital agronomy adoption.*



Since farmer value the recommendations of fellow farmers similar with the findings of Kaur (2022), targeting influential and Innovative farmer group as "**Early Adopters"** can improve the utilization of digital agronomy advisories. This type of farmer is receptive to new technologies and have high likelihood to use available digital advisories in the market. Early adopters should be at the base of the pyramid being targeted first and eventually influenced Exploratory farmer.

Exploratory farmers are undecided but open to digital technologies given sufficient time and information on the value of such technologies. Early adopter farmers can be more influential to them better than from government extension agents and private companies. Their decision and mindset can be changed through the influence of Early Adopters. Other motivations can also influence Exploratory farmers to try and adopt digital technologies. Some farmer respondents stressed that incentives or any form of encouragement could change the acceptability and mindset of this type of farmers.

The least priority group to be targeted are the *Satisfied farmers*. These farmers are generally comfortable on their farming operations. They are contented on the way they access agronomy advisories. They are at ease on their existing ways of farming. Furthermore, they are normally not interested to new technologies due to several limitations such as finances and difficulty in learning new things or technologies. However, the belief and perceptions of these farmers can change if they experience severe problems in their farming. Based on interviews, these types of farmers become open to new ideas, information and support when they experience significant crop losses and failure. When unfavorable incidence like this happens, there is still an opportunity for these farmers to access and learn digital advisories.

Based on study, farmers indicated that they usually access digital platforms with the help of their children. One of the farmers in Kediri, East Java, Indonesia has a college graduate daughter with the degree in Agriculture. Another farmer in Sulawesi, Indonesia indicated that communication to him is through his child who is capable and knowledge of digital technologies. Similar case in some farmers in the Philippines, where knowledge on digital technology of the children and family members of farmers are leveraged in communication or accessing social media crop advisories (Figure 28). Digitally inclined intermediaries can also be extension agents, input and output dealers, microfinance institutions, equipment suppliers, and seed companies (Kamau et al., 2022).

Figure 28. *Leveraging "Intermediaries" to drive interest and adoption of digital technologies.*

Simple, easy, relevant, and valuable information on appropriate digital platform is preferred by farmers. During the testing of SpidTech mobile in Capiz, there are several farmers who face several challenges. These include lack of smartphone, lack of internet source like Wi-Fi or mobile data, difficulty on downloading and using the mobile app, limited type or kind of information available, and some functionalities are not working properly. The demonstration of pest identification using the mobile app did not provide accurate information of the pest specimen. This cause loss of interest of farmer and start the disengagement of mobile app utilization.

Theorizing the Complexity theory in communication, the farmer who are the end user of the digital crop advisories are considered as the agents in the e-farming system. Each farmer agent has unique and similar motivations affecting their digital adaptiveness (Figures 26, 27, and 28, and Table 7). Different agents in the e-farming system respond to different communication platforms such as social media and mobile applications.

Understanding both the critical agents in creating and communicating the advisories and the different farmer agent personas as well as their interactions can be leveraged in driving behavioral adaptiveness and high utilization of digital crop advisories. The improvement of farmer income is a very important factor in the system. E-farming system should not just cover the crop agronomy advisories but the whole value chain including access to financing, stable commodity prices, and efficient delivery to customers (B2B). These can be achieved when all the agents in the e-farming system are positively adapting and driving a bigger outcome than its individual agent can attain.

Chapter VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Complexity theory provides a clear understanding of the knowledge transfer in e-farming system based on this study. The identified agents, network of agents, and their interactions provide insight and recommendation of a Planning-Communication-Evaluation or PCE model (Figure 26) that can be utilized to improve the content creation of organizations and adaptiveness of farmers to digital advisories. The responsible use of Artificial Intelligence (AI) application across these agents and network of agents in the e-farming system can also improve the efficiency and effectiveness of knowledge transfer.

The core disciplines in a complex system including Information, Dynamics, Computation, and Evolution were leveraged to better understand the e-farming system. Organizations or companies developing the digital contents need to have a comprehensive analysis of all the agents affecting the whole system to plan and execute the knowledge transfer effectively. Similarly, knowledge of different farmer personas and motivations can increase the digital adaptiveness among the larger farmer group.

E-farming has become a ubiquitous term in the modern educational landscape in agriculture sector. E-farming refers to any agriculture or food production instructional process that utilizes electronic technologies to access educational materials and deliver instruction. This also include E-commerce, which refers to the marketing of products and services using the internet technology. In knowledge transfer of e-farming, there are interacting adaptive agents in the entire ecosystem under Complexity theory affecting this whole E-Knowledge Management process. E-farming knowledge transfer has several advantages:

- Flexibility: Learners can access digital advisories at their own pace and convenience.
- Accessibility: E-learning can break down geographical barriers and provide education to a wider audience, although language is an important consideration.
- Variety of formats: E-learning can include social media and mobile e-learning, which was the focus of this study but may also include online courses, webinars, video tutorials, and interactive simulations.
- Personalized learning: Technology can enable tailored learning experiences based on individual needs and preferences of farmers.

Farmer motivation and needs assessment should be the topmost priority before starting any digital crop advisories. Understanding the needs of the farmer will enable the organizations to develop tailor fit advisories. Such information and communication messages including content type and platform becomes relevant and beneficial to farmers. The muted voices of farmer under Critical Theory offers discursive planning and analyses including monitoring and impact assessment. The success metrics of digital advisories should be identified.

Digital advisory programs should be spearheaded and supported by the leaders of the organization. The success of e-farming knowledge transfers depends on the influence of different factors - infrastructure, content information, content types, content delivery, and continuous assessment, feedbacking, and improvements.

With Early Adopters and Intermediaries concepts or approaches, the muted perspectives of farmer or domination of power of companies under Critical Theory can lead to discourse that can be optimized to improve utilization and eventually deliver positive impact to farmers and the community. Moreover, social motivations, content, and communication messages, and platforms that are simple, relevant, and applicable to factors based on needs and problem assessment are importance considerations to drive more usage of digital advisories.

Leveraging the use of digital advisories can reach more farmers and support the development of the society in a faster pace compared to the traditional way of communicating crop advisories. Although there are challenges on the development, adoption, and expansion of digital advisories, the potential of e-farming to bring positive impacts in Agriculture outweighs such challenges. E-farming knowledge transfer is more scalable and efficient. The validity and propriety of the content, platform, as well as processes developed from digital crop advisories should be evaluated and assessed critically. Beneficial information and simple, accessible, and effective communication platform can unravel the potential of digital technologies in farming.

E-farming knowledge transfer can be asynchronous, synchronous, and hybrid learning. In asynchronous learning, farmers can learn the advisories at their own pace, without real-time interaction with the content or advisory developers. In synchronous learning, farmers interact with the host or organization representatives such as during Facebook live events. Hybrid learning is a combination of asynchronous and synchronous learning.

E-farming knowledge transfer have several advantages over traditional approaches.

- Cost-effective: E-farming can often be more affordable than traditional face to face field or classroom instruction.
- Self-paced learning: Farmers can progress through the material at their own speed.
- Scalability and global reach: Digital and online content can reach many learners, including global reach without requiring additional physical resources. CABI and IRRI e-farming advisories are examples of e-learning that connect learners from around the world.

Despite the advantages of e-farming knowledge transfer approaches, organizations should consider the following best practices for effective knowledge transfer in digital environments:

1. Overcome technological barriers: Ensuring that farmers have the necessary skills and access to technology to effectively utilize digital tools for knowledge transfer.
2. Address cultural differences: Recognizing and addressing cultural differences that may impact how knowledge is shared and received. Understanding the farmer motivation and social needs based on their cultural status is crucial.
3. Promote a culture of knowledge sharing: Creating an ecosystem culture that values and rewards knowledge sharing. This also includes the collaboration among agents from the developer of digital advisories up to the utilization of early adopters, farmer influencers, and farmers as a whole.
4. Utilize technology effectively: Leveraging digital tools and platforms to facilitate knowledge transfer, such as collaboration tools and online learning platforms including social media, and knowledge management systems.

5. Provide ongoing support: Offering ongoing support and resources to help employees apply the knowledge they have acquired.

Digital advisories can bring information into higher level of communication. It brings out knowledge, develop skills, and change attitudes of farmers. Such use when regulated and monitored properly can bring positive impact to the lives of the farmers and the community. New advances in digital technologies can also encourage young generations to venture into farming. A farming envisioned to be innovative, digitally enabled, motivating, and financially viable. A farming system that will help solve challenge of aging farmer population and will help continue to produce food productively and sustainably to feed the increasing world population.

Conclusion

Knowledge management in digital environments together with Artificial Intelligence applications can provide faster and enhanced reach to the targeted stakeholders. However, e-farming knowledge transfer and management is a complex system composed of many agents. The complex system has adaptive networks of adaptive agents exchanging matter, energy, and information.

Complexity theory clarifies and provides a discourse in understanding different agents in an e-farming complex system. Agents can be biotic or abiotic that are interacting, adapting, and organizing itself without a central control to function differently that is bigger that its individual component.

Digital crop advisories must consider the pandiscipline social agents (i.e. agriculturist, computer scientist, economist, sociologist, and communications specialists) and their interactions to ensure its' effectiveness and impact to farmers.

Agents must create emergent outcomes that lead to the development and enhancement of farmer productivity, income, and social status. Digital socialism where the struggle of internet and media should highlight four key factors, which include people, infrastructure, communication & content delivery, and developmental impact. In the creation of the digital advisory content and platform delivery, the end user or farmer participatory approach should be given the highest importance.

The voice of farmers should not be muted but rather need to be considered with utmost importance by the content developer companies or organizations. This participatory and bottoms-up approach of need assessment based on Knowledge, Attitudes, Skills, and Aspirations can enlighten the real need and motivation of farmers to adapt e-farming system. Communication should be commons-based where meaning arises from the voice and freedom of farmers in terms of the digital advisory content they need.

The adeptness of youth and/or innovative farmers into digital farming innovations and technologies can be leveraged to address the challenges in farming such as low income, access and communication of crop advisories, and aging farmer population. The agents in the e-farming system needs to have dynamic, relevant, and impactful content, platforms, and delivery. Moreover, farming must provide stable and better income, and help mitigate climate change to entice more youth into farming.

Farmers were more likely to adopt digital extension services if they believed they were socially accepted, capable of using them, and found them beneficial. Complexity theory underscores these factors in the proposed PCE (Planning-Communication-Evaluation) model having various agents and interactions in the e-farming knowledge transfer.

Implications

The Planning-Communication-Evaluation (PCE) model discusses how to improve the effectiveness of digital communication and improve the digital adaptiveness among farmers. The classification of different farmer personas (Innovative, Experimental, and Satisfied) and use of intermediaries can improve the proportion of farmers utilizing and benefiting from knowledge transfer of e-farming advisories. These constructs underpin and enables discourse of Complexity theory in communication in e-farming system or Agriculture as whole.

The findings imply the criticality of understanding the right digital advisory content and platform based on social information to produce sociality. Digital society of farmers can emanate from themselves as users, workers, citizens, or agent in the form of a participatory digital democracy rather than corporation hegemony.

Government agency, including policy makers and research agencies can apply the learnings of this study to enhance digital advisories to farmers. For instance, policies on digital advisories can be developed to regulate and protect the rights of farmers. Research agencies such as the funding agencies should ensure continuity of digital advisory projects and should also focus on its' impact and development in the society.

For private sectors or companies, a balanced content of general advisories and product marketing can increase the utilization and trust of farmers. The use of incentives can augment the access and utilization of digital advisories. Similar with government driven digital advisories, private organizations need to understand and prioritize the need of farmers before its' development.

In both government and private organizations, the data and intellectual property rights of all the social actors should be considered. The use of open source, public platforms, or social networking such as Facebook in communicating digital advisories might cause vulnerabilities to companies or farmers.

Recommendations

Based on the learnings from the KII and FGDs of farmers and content developers, the following recommendations can be derived:

1. The (Planning-Communication-Evaluation) PCE model provides pedagogy on knowledge transfer in e-farming system augmenting the discourse on e-knowledge management for development. E- Knowledge Management is the comprehensive term used for the process of transferring digital information, particularly e-farming advisories in the field of agriculture and food production. It encompasses the entire lifecycle of knowledge, from creation and capture to dissemination and utilization. It is a holistic approach covering all aspects of knowledge, including creation, storage, retrieval, application, monitoring, evaluation, impact, and re-designing.

   The digital focus in Knowledge Management (KM) can address the challenges and opportunities of managing knowledge in a digital age. Similarly, the process-oriented approach emphasizes the systematic and structured approach to managing knowledge, ensuring efficient transfer and utilization.

The complete social system from organizational strategies on digital advisories, infrastructure, and farmer participation is key to the success to drive more reach and impact to farmers and the community. Kamau et al. (2022) highlighted several reasons to enhance digital adaptiveness of farmers. These should include improved network connectivity, usefulness of mobile apps, versatile & more functional devices, and cost-effective apps or services. All the agents in the ecosystem should be adaptive and create bigger impacts (emergent behavior) more than the impact of each individual agents. The insights from Complexity theory can be utilized to make e-farming knowledge transfer effective and sustainable.

2. The social motivations of farmers should be understood well and prioritized when creating e-farming advisories. The common risks of farmers such as negative impacts of weather into farming should be considered. Weather advisories and farming crop insurance can be incorporated in the topics of digital advisories. Farmers need to get information of the weather in relation to the best timing of planting their crops to avoid crop losses due to climate change. IoT real time weather monitoring and practical applications should be included in the advisories.

   The prices of commodities and access to buyers or traders is another topic needed by farmers. The addition of commodity price and market linkage can improve utilization of digital advisories. Moreover, the problem of labor shortage in farming has become apparent. The access to service providers of advanced farming implements such tractors, Unmanned Aerial System (UAV) or drones, and robots should be included in the digital advisories. These advanced machines and technologies can address issues of labor in farming operations, such as land preparation, planting, fertilizer application, and pest management.

3. Identification and tailor fit communication to the different type of farmer personas is needed. It is highly recommended to focus and develop experimental and innovative farmers first, can be called “early adopters”. The development of content and platform should be based on farmer need analyses or participatory approach. This can drive success given that the early adopters farmers with high affinity and motivation of the digital technology will have strong voice to influence other farmers.

   It is also recommended to utilize digital savvy intermediaries such as innovative farmers and digitally inclined children or relatives of farmers. Digitally inclined intermediaries can also include extension agents, input and output dealers, microfinance institutions, equipment suppliers, and seed companies (Kamau et al., 2022). These intermediaries play an important role on personalized and effective learning, which is much needed by the aging and technology averse farmers.

   The digital farming society can be produced and can expand the network of digitally- enabled farmers through the mediation of “early adopter” farmers and digitally inclined intermediaries or social actors. Utilize these farmers as champions and catalysts to influence other farmers to use digital platform and advisories. The produced society will reproduce and expand the sociality of digital farmers capitalizing on the farmer-to-farmer influence based on results of this study.

4. There is a need to maximize the e-farming advisory communication of government and neutral or non-profit organizations to improve the trust and acceptance of farmers. Government agencies such as the Department of Agriculture in the Philippines and the Ministry of Agriculture in Indonesia can enhance digital innovations in farming systems to encourage young people and new generation farmers to pursue agricultural endeavors. In the case of profit-oriented organizations, companies should provide more advisories that can benefit the farmer in terms of improvement of their income.

   Collaborations across public and private sectors should be strengthened on the whole value chain or whole system of farming. These can be related to information sharing of crop advisories or joint development of crop advisories. These agents can create beneficial outcomes to marginalized farmers and can entice new generation of farmers to ensure food security.

5. The increased use of Artificial Intelligence (AI) across different industries in the society can be utilized in creating content and delivering relevant and impactful information to farmers. There are available AI Large Language Models (LLM) that can generate e-farming advisories that can simplify complex agricultural challenges, enhance decision making, and improve the efficiency of agricultural image processing (Sapkota et al., 2024 and Peng et al., 2023). These can improve

the efficiency and number of contents that are created. For instance, local language contents and effective video contents can be created using AI tools.

In addition, AI has also benefit on effective targeting of advisories to the appropriate personas or stakeholders. For instance, the posting or reels in Facebook, Tiktok, and Instagram utilize AI in providing the feeds related to the accessed topics. The targeted audience of specific content is precise based on the access information interest and pattern.

The use of efficient and interactive messenger bots as communication platforms like WhatsApp can provide timely and relevant advisories to farmers. It is also critical to engage and maintain the interest of farmers in utilizing digital advisories such as improvement of mobile app functionalities, such as accuracy of sensors in pest identification and nutrient deficiency guide.

The applications in Agriculture of Artificial Intelligence, Internet of Things, modern technologies like Unmanned Aerial Vehicles or drones, robots, and advanced digital media can entice new generation of farmers, especially when the profitability in farming is realized and optimized.

6. A comprehensive metrics or Key Performance Indicators focused on learning outcomes, behavioral change, and organization/ business outcomes need to be determined:

   For Learning Outcome, the following should be considered:

   a. Knowledge acquisition: Measuring how much farmers have learned from the content.

b. Skill development: Assessing whether farmers have developed new or improved skills.

c. Attitudinal changes: Evaluating if the content has influenced farmers' beliefs or attitudes.

For Behavioral Changes, it should consider the following:

a. Increased engagement: Measuring whether the content has increased user engagement or participation.

b. Changed behaviors: Assessing if the content has led to changes in behavior, such as increased product usage or improved performance.

And lastly for Organization or Business Outcomes, the following should be measured:

a. Improved customer satisfaction: Assessing whether the content has enhanced farmer customer satisfaction or loyalty.

b. Increased sales: Measuring whether the content has contributed to increased sales or revenue.

c. Cost savings: Evaluating if the content has helped reduce costs or improve efficiency.

As a summary, Complexity theory and the abovementioned recommendations suggest potential impact and further amplification of digital advisory knowledge transfer and usage in e-farming system. Traditional and less popular media platforms often have slower adoption rates and have limitations to reach millions of smallholder farmers. The adoption of digital advisories on crop production, climate mitigation, financing, and e-commerce is crucial for influencing farmer behavior and improving their productivity, income, and social standing within their communities. The rise of artificial intelligence applications and digital innovations in Unmanned Aerial Systems (UAVs) or drones, sensors and the like can also attract younger generations to consider farming as a viable career path.

Complexity theory underscores the production of complex behavior, patterns, or structures through self-organization and emergent behaviors in a complex e-farming made of interacting individual and simple agents in the network. Each agent either biological (people or organization pandiscipline, crop production), technological (infrastructure, signals), or social (motivations, behavior) adapts and improves itself in decentralized way. Such complex behavior arises from the interrelationship, interaction, and inter-connectivity of elements within a system and between a system and its environment. The “last mile” challenges on communication or infrastructure can be addressed with the applications of complexity theory into the complex e-farming system.

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APPENDICES

APPENDIX A

Interview Questionnaire for Focus Group Discussion and Key Informant Interview

Digital Usage Questionnaire
Farm Profile
1. Location or Address
2. What crops are you growing?
3. Do you own a mobile phone?

Motivations and Digital Acceptance and Recommendations
1. Why is farming important to you?
2. Do you use or get digital information in farming? What are those?
3. Why or why not use digital tools in getting farming information?
4. To whom do you usually get the information on the agronomy cropping practices?
5. What are your recommendations for the farmers to maximize the use and benefit from digital advisories?

Content Developers Questionnaire
1. What are the factors that you consider in developing the crop advisories?
2. How do you determine the type of content and kind of digital platform to use?
3. What are the challenges that you face in creating and utilization of crop advisories?
4. Kindly provide suggestions on how to improve utilization of digital crop advisories.

APPENDIX B

Source: BPS Statistica, 2023, [Complete Enumeration Results of the 2023 Census of Agriculture - Edition 1 - BPS-Statistics Indonesia]