

chapter i

general introduction

1.1 background

agriculture is one of the most important economic sectors in many countries, especially in developing countries like indonesia. it is one of the sectors that supports improving the welfare of indonesian society (jamil et al., 2023). the role of the agricultural sector in indonesia is also vital because it's the third-largest contributor to gross domestic product (gdp), which drives national economic growth. based on data (bps, 2023), the agricultural, forestry, and fisheries sectors will contribute 12.40 percent to the indonesian economy in 2022. even though during the covid-19 pandemic, the indonesian economy experienced contraction, the agricultural sector was able to continue to grow positively (malahayati et al., 2021). over the last three years, this sector has continued to experience positive growth, namely growing around 1.77 percent in 2020, then in 2021 growing by 1.87 percent, reaching around 2.25 percent in 2022.

the map of indonesia suggests a high diversity in types of agriculture. the archipelago has countless different islands that stretch out over thousands of kilometers from east to west, above and below the equator. it has a rich biodiversity and the techniques the people developed to benefit from the natural environment have distinct features on each of the islands. despite all this diversity, some clear patterns can be detected, based on three major factors. the first is the monsoon climate that divides the year into a dry and wet season with an overall high precipitation of roughly 1,700–3,000 mm in the lowlands and over 6,000 mm in the mountainous regions. the combination of high rainfall and, for tropical conditions, not excessively high temperatures throughout the year creates a favorable climate for many different crops. the geology and elevation of the landscape are second factors (maat, 2016).

the agricultural sector of indonesia comprises large plantations (both state-owned and private) and smallholder production modes. the large plantations tend to focus on commodities that are important export products (palm oil and rubber), while the farmers' groups focus on rice, soybeans, corn, fruits, and vegetables (quincieu, 2015; matalitti *et al.*, 2024) .

with its vast and abundant fertile soils, indonesia is a major

global key producer of a wide variety of agricultural tropical products, and although agriculture's share of the country's gross domestic product (gdp) has declined markedly during the last five decades, it still provides income for the majority of Indonesian households today (Osaki & Tsuji, 2015). In 2012 this sector employed around 49 million Indonesian individuals, which represents 41 percent of the total Indonesian labour force. But although in absolute numbers the agricultural workforce keeps growing, its relative share of the total Indonesian workforce has declined significantly from 55 percent in the 1980s to 45 percent in the 1990s and currently to 41 percent. Only during the Asian financial crisis in the late 1990s, this share grew significantly because unemployment in both the industry and services sectors was absorbed by the agriculture sector (Syuaib, 2016).

Indonesia's agricultural development is deeply shaped by its geographical and ecological diversity. As an archipelagic country extending across the equator, Indonesia encompasses a wide range of agroecological zones influenced by monsoon climate systems, volcanic activity, and varied topography (Rondhi *et al.*, 2020; Suwandari *et al.*, 2020). Rice remains the dominant staple crop across most regions of Indonesia and has played a central role in shaping agricultural institutions, land-use systems, and rural social organization (Mardiharini *et al.*, 2023). The widespread cultivation of rice facilitated the development of irrigation infrastructure, collective labor arrangements, and farmer group institutions that persist to this day. In contrast, some eastern regions of Indonesia developed distinct subsistence systems based on sago and other forest-based resources, reflecting long-standing adaptation to rainforest ecosystems and limited reliance on permanent crop cultivation (Setiawan *et al.*, 2023). These diverse agricultural systems highlight the importance of context-specific development strategies that take into account ecological, cultural, and institutional differences across regions. Structurally, Indonesia's agricultural sector is characterized by a dualistic production system. Large-scale state-owned and private plantations dominate export-oriented commodities such as palm oil and rubber, while smallholder farmers account for the majority of food crop production, including rice, maize, soybeans, fruits, and vegetables (Patria, 2025).

Smallholder farmers are typically organized into farmer groups (kelompok tani), which function as the primary institutional

units for agricultural extension, technology dissemination, and access to government support programs. although agriculture's relative share of gdp has declined over the past five decades, the sector continues to provide livelihoods for a substantial proportion of the population. in 2012, approximately 49 million indonesians, around 41 percent of the national labor force, were employed in agriculture (osaki & tsuji, 2015). however, the sector faces persistent structural challenges, including aging farmers, declining youth participation, land fragmentation, and increasing conversion of agricultural land for non-agricultural purposes. in response to these challenges, agricultural extension services have long been recognized as a critical mechanism for enhancing farmers' knowledge, skills, and adaptive capacity.

extension services are expected to facilitate technology adoption, improve productivity, and strengthen farmer institutions. in indonesia, agricultural extension is formally institutionalized through agricultural extension centers (balai penyuluhan pertanian, bpp), which serve as the frontline agencies responsible for delivering extension services and coordinating farmer groups at the local level. however, conventional extension approaches, largely based on face-to-face group meetings and top-down information dissemination, have increasingly proven inadequate in addressing the growing complexity of agricultural production, market integration, climate variability, and technological change (moore et al., 2021).

within this broader national context, digital agricultural extension has emerged as a promising strategy to enhance the effectiveness, reach, and inclusivity of extension services. digital agricultural extension refers to the use of information and communication technologies (icts) such as mobile phones, internet-based platforms, social media, and digital information systems to support advisory services, knowledge exchange, and stakeholder coordination. digital approaches have the potential to overcome temporal and spatial limitations of conventional extension, provide timely and customised information, and strengthen interaction between extension workers and farmers (peng et al., 2020). however, the effectiveness of digital extension strategies depends heavily on local institutional capacity, digital literacy, and socio-economic conditions.

maros district, located in south sulawesi province, provides

a particularly relevant regional context for examining the transformation of agricultural extension through digitalization. the district lies adjacent to makassar city, one of eastern indonesia's major urban and economic centers, and exhibits a combination of rural and peri-urban characteristics. maros district encompasses diverse agricultural landscapes, including irrigated lowland rice fields, upland farming areas, karst ecosystems, and coastal zones. rice cultivation dominates lowland areas, supported by irrigation infrastructure, while upland areas are characterized by secondary crops, horticulture, and livestock systems (suswadi & irawan, 2023).

agriculture remains an important livelihood source for rural households in maros district, with farmer groups serving as the main institutional mechanism for organizing production and accessing extension services. agricultural extension centers (bpp) in maros district play a central role in coordinating extension workers and implementing government agricultural programs. however, the district faces multiple development pressures that complicate agricultural extension efforts. rapid urban expansion, infrastructure development, and increasing land conversion have reduced the availability of agricultural land, leading many farmers to treat agriculture as a secondary occupation. this shift has weakened farmer group cohesion and reduced participation in conventional extension activities (sumandiyar et al., 2025).

at the same time, digital infrastructure in the maros district has improved in recent years, particularly in terms of mobile phone ownership and internet connectivity. despite this progress, significant disparities remain in digital literacy, access to relevant agricultural information, and the effective use of digital platforms by both farmers and extension workers. extension activities in the district continue to rely heavily on traditional communication methods, while the integration of digital tools remains uneven and largely experimental. farmers often depend on government assistance programmes rather than engaging in self-driven innovation and collective learning processes, reinforcing patterns of dependency that limit institutional resilience (nurman, et al., 2022).

the primary goal of the agricultural extension sector, according to the head of the maros agricultural extension center, is to collaborate with organizations that are involved in farming development, such as government agencies, non-governmental organizations, research institutes, and private businesses, to

facilitate the implementation and upkeep of digital agricultural extension programs in maros regency. this is expected to enhance rice production in maros, generate employment opportunities in the region, and reduce rural-to-urban migration, thereby contributing to increased income for farmers (salam et al., 2023). however, rice farmer groups often face obstacles such as lack of training and access to agricultural technology (santoso et al., 2023) (santoso et al., 2023; jamal et al., 2023).the fact that certain rural regions in maros regency don't have easy access to the internet and electricity makes this problem even worse. this makes the difference between agricultural technology and the way things are done on the ground even bigger (rokhani et al., 2021). thus, there is still a gap between the ease of acquiring and using innovative agricultural technologies. this makes it more challenging for farmer groups to leverage new opportunities in digital agriculture fully.

digital agricultural extension services are fundamental to advancing farmers' knowledge, productivity, and adaptive capacity. however, conventional face-to-face extension systems in indonesia, especially in maros, continue to encounter significant challenges, including limited extension personnel, inadequate coverage, and high operational costs. in response, the government and development agencies have promoted digital agricultural extension platforms such as cyber extension and simluhtan as innovative mechanisms to enhance information dissemination, facilitate knowledge exchange, and strengthen linkages between farmers and extension agents. despite these advancements, the participation of farmer groups in digital extension programs within maros regency remains inconsistent, thereby constraining the potential benefits of these initiatives. maros regency, a region distinguished by its intensive rice-based farming systems and active farmer groups, presents a critical context for examining the effectiveness of digital agricultural extension. while some farmer groups have successfully integrated digital tools to access information and improve decision-making, others exhibit minimal engagement due to constraints related to digital literacy, infrastructure, motivation, and institutional support. such disparities highlight the uneven diffusion of digital innovations and suggest the presence of underlying determinants that influence participation.

these conditions emphasize the need for a more adaptable and strategically designed digital agricultural extension system that

responds to local needs and institutional realities. maros district, therefore, serves as a key case for exploring how digital agricultural extension strategies can be implemented to strengthen farmer groups, improve extension performance, and support sustainable agricultural development under decentralized governance. by placing digital extension within the specific socio-economic and institutional context of maros regency, this study aims to deepen understanding of how digital transformation can reshape agricultural extension systems in indonesia and similar developing countries.

1.2 problem statement.

despite policy recognition of agricultural extension as a key driver of rural development, the institutional performance of extension services in maros district remains limited in addressing farmers' evolving needs. extension activities are often constrained by weak coordination among extension workers, farmer group leaders, and group members, resulting in fragmented service delivery and limited farmer engagement. the effectiveness of the extension system is further undermined by human resource constraints, aging extension personnel, and insufficient integration of digital communication tools.

in recent years, digital agricultural extension has emerged as a promising strategy to address these limitations by using information and communication technologies (icts) such as mobile applications, online platforms, and digital information systems to facilitate knowledge exchange and advisory services. while indonesia has introduced several digital initiatives—such as cyber extension and simluhtan the implementation of digital extension systems at the local level remains uneven. in regions such as maros regency, disparities persist in digital literacy, access to digital tools, and institutional readiness among farmers and extension workers. as a result, participation of farmer groups in digital extension programs remains inconsistent.

moreover, existing research on digital agricultural extension has largely focused on individual-level outcomes such as technology adoption and information access, while limited attention has been given to collective institutional outcomes, particularly the development and performance of farmer groups. given that farmer groups serve as the main organizational units for extension delivery in indonesia, understanding how digital extension influences group participation, coordination, and institutional capacity is essential.

therefore, this study addresses three interrelated problems: the need to understand how agricultural extension strategies are implemented within local institutional contexts; the determinants that influence farmer groups' participation in digital extension; and the role of digital agricultural extension in strengthening farmer group development.

based on the background stated above, the research questions will be as follows:

1. how do agricultural extension workers conceptualize and implement digital agricultural extension strategies in maros district?
2. what types of agricultural extension services are provided through digital and conventional channels, and how are these services determined?
3. how do digital agricultural extension strategies influence the development and performance of rice farmer groups in maros district?
4. what institutional and relational dynamics characterize the interaction between extension workers and farmer groups in the context of digital agricultural extension?

1.3 research objectives

the primary objective of this study is to examine the benefits and effectiveness of the agricultural extension center (balai penyuluhan pertanian /bpp) in maros district, with particular emphasis on the extent to which agricultural extension services, especially digital extension services—are aligned with the actual needs of farmer groups. this study seeks to assess how well existing extension systems respond to farmers' demands and how such alignment contributes to the development and empowerment of farmer groups in maros district. specifically, this research explores digital agricultural extension services implemented by both government and private-sector actors, farmers' perceptions of their agricultural needs and extension services, and the degree of congruence between extension programs and farmers' practical requirements. in addition, the study investigates how farmers independently fulfill their farming needs, including access to information, technology, markets, and institutional support. by integrating these perspectives, the research aims to provide a

comprehensive understanding of the effectiveness of digital agricultural extension within the local agricultural innovation system.

the broader objectives of this study are the following:

1. examine current agricultural extension methods in maros regency and identify improvements to support sustainable agriculture and strengthen farmers' capacity in maros regency.
2. analyze key internal and external factors influencing farmer groups' participation in digital extension, and provide evidence-based insights for more effective, inclusive policies.
3. assess how digital agricultural extension supports farmer group development, and identify key stakeholders in maros to improve service delivery through collaborative, facilitative, learning-oriented approaches in maros regency.

1.4 the research benefits

the benefits of this research are:

1. theoretical benefits: it is hoped that this research can be used as a vehicle for applying the knowledge gained in colleges of agriculture, especially those related to agricultural extension.
2. practical benefits
 - a. for academics, this research aims to contribute to the existing literature on enhancing farmer institutions' strategies.
 - b. for the government, it is hoped that this research can contribute to determining policies to strengthen digital agricultural extension centers.

1.5 research scope

this research focuses on analyzing digital agricultural extension strategies aimed at strengthening the development of farmer groups in maros regency, south sulawesi, indonesia. the scope of the research is limited to digital extension services implemented through the agricultural extension centers (balai penyuluhan pertanian – bpp) in maros, utilizing information and communication technologies such as online information systems, mobile applications, and social media platforms to facilitate knowledge dissemination, communication, and decision-making processes among farmers. in this research, extension workers and farmer groups are considered the primary unit of analysis, with particular attention given to collective institutional outcomes, including farmer participation, information exchange, leadership

dynamics, and capacity development within the groups. the study also examines the roles of agricultural extension workers and local institutional arrangements in supporting the implementation of digital extension practices. geographically, the research is confined to maros regency and concentrates on existing digital extension practices. therefore, the study does not include cross-regional comparisons, experimental technology testing, or detailed assessments of agronomic productivity and biological impacts.

1.6 research gaps

although the increasing interest in digital agricultural extension, several gaps remain in understanding its role in strengthening farmer groups. from a theoretical perspective, most studies focus on technology adoption and information dissemination at the individual farmer level, often using innovation diffusion or technology adoption frameworks. these approaches provide a limited explanation of how digital extension contributes to collective institutional processes, such as participation, knowledge exchange, and leadership within farmer groups.

from an empirical perspective, previous studies mainly examine individual outcomes such as information access, productivity, and technology adoption (kamanda et al., 2017), while overlooking how digital extension impacts group capacity, participation, leadership, collaboration, and collective decision-making. this gap is especially noticeable at the district level, where farmer groups serve as the main institutional unit for extension delivery.

the indonesian agricultural extension research has largely emphasized conventional extension systems or ict adoption. although digital platforms such as cyber extension and simluhtan have been introduced, there is still limited evidence on how these digital initiatives influence the institutional development of farmer groups, which are the main units of extension delivery in indonesia.

the research on digital agricultural extension in maros regency remains scarce, despite its importance as a major rice-producing area. existing studies mostly focus on productivity and extension performance, while the role of digital extension in strengthening farmer group participation and institutional capacity is still insufficiently explored (davis & rasheed sulaiman, 2014; laela & azhari, 2023).

1.7 research novelty

this study provides several novelties.

first, it shifts the focus from individual farmers to farmer groups as collective institutions. second, it provides empirical evidence from maros regency, offering localized insights into digital agricultural extension in indonesia. finally, it integrates digital extension access, utilization of digital tools, farmer participation, and farmer group development into a single analytical framework.

1.8 research contribution

this research contributes theoretically by expanding the understanding of digital agricultural extension from a collective institutional perspective. empirically, it provides quantitative evidence on how digital extension influences farmer participation and farmer group development. practically, the findings offer policy recommendations for improving digital extension strategies and strengthening farmer groups within the indonesian agricultural extension system.

chapter ii

agricultural extension strategies in maros regency: a review of approaches and methods.

abstract

this study examines the approaches and methods applied in maros regency, indonesia, focusing to institutional strengthening, the changing roles of extension workers, stakeholder collaboration, and the integration of digital agricultural advisory tools. using a qualitative descriptive design supported by thematic analysis, the study draws on primary data from interviews with extension workers and secondary data from peer-reviewed literature, policy documents, and agricultural statistics. the results show that the agricultural sector in maros aligns closely with national policy directions by upgrading balai penyuluhan pertanian (bpp) into kostratani hubs, promoting data-driven decision-making, and enhancing human resource competencies through structured training and mentoring. extension workers are now hybrid facilitators, combining field-based advisory services with ict-supported communication through digital reporting apps, whatsapp, and simluhtan. this is a change from traditional knowledge transmitters. individualised extension support is becoming more and more preferred by farmers, which is consistent with trends in south-east asia where adoption rates and decision-making are enhanced by household-level advisory interactions. gaps in digital literacy, short visit durations brought on by excessive workloads, and incentive-driven performance swings, however, continue to be issues. to increase the effectiveness of extension services, it is essential to strengthen farmer groups (poktan/gapoktan), improve multi-stakeholder collaboration, and incorporate climate-smart practices. the study comes to the conclusion that the most adaptable and context-appropriate way to improve productivity, farmer resilience, and sustainability in maros regency is through a hybrid extension model that strikes a balance between digital tools, individualised advisory services, and strengthened institutional governance. these findings offer useful information for policymakers looking to update rural advisory systems and add to the expanding body of research on digital agricultural extension in southeast asia..

keywords: digital agricultural extension, maros regency, extension approaches, farmer groups, ict-based advisory services.

2.1 introduction

indonesia's agricultural sector is central to food security and rural livelihoods, with government programs consistently emphasizing food provision and farmer welfare. by strengthening farmers' technical and managerial skills, agricultural extension (ae) plays a crucial role in this strategy, enhancing productivity, reducing losses, and promoting the adoption of new technologies ((azhari et al., 2025). extension directly improves farmer performance and welfare at the farm level while also strengthening the resilience of the food system at the national level. in line with the agricultural revitalisation programme (arp) 2025, which aims to increase production in 14 strategic commodities, ae has been institutionalised through the national agricultural extension system (aes) under law no. 16/2006 ((lubis, 2012).

particularly in developing nations where the majority of people rely on farming for social stability, food security, and income, agriculture continues to be a vital pillar of national development. in indonesia, agriculture is important not only as a source of food and raw materials but also as a catalyst for regional economic expansion and rural employment. according to recent evaluations, the industry must support smallholders and farmer groups while adjusting to structural change, climate variability, and market integration (world bank, 2020).

supported by fertile soil, irrigation facilities, and a robust farming culture, maros district, one of south sulawesi's most notable agricultural regions, has long been acknowledged as a significant rice-producing area and a "rice barn" for the province (nurman et al., 2022). but like many other agricultural regions, maros is currently dealing with structural and technological issues related to shifting land uses, environmental stresses, and changing socioeconomic circumstances that call for constant innovation in agricultural development plans. to increase productivity, sustainability, and welfare outcomes, agricultural extension has become an essential tool for enhancing farmers' knowledge, skills, attitudes, and capacity for informed decision-making (saridewi & annisa, 2025). according to (massimi et al., 2021), agricultural extension is commonly understood as an educational, communication, and facilitation process designed to help farmers identify problems, access

innovations, adopt relevant technologies, and apply improved farming practices in their local context.

in indonesia, extension policies and practices have undergone a gradual transformation from conventional, technology-push, and top-down models toward more participatory, demand-driven, and pluralistic systems that engage a range of actors (cahyono & agunga, 2016; sumandiyar et al., 2025). as government initiatives increasingly emphasise digital transformation, sustainability, and inclusive rural development, extension workers are now expected to perform multiple roles: not only as technology disseminators, but also as educators, facilitators, motivators, mentors, and mediators supporting farmers in dealing with complex challenges such as climate variability, market volatility, input access, and risk management. this evolution highlights the need for extension strategies that are relevant, adaptive, and context-appropriate for specific regions such as the maros regency.

the agricultural sector of maros demonstrates both substantial opportunities and significant constraints that shape how extension strategies should be designed and implemented. on one hand, maros benefits from productive paddy fields and other key commodities, and over the last two decades, it has contributed a notable share of rice production in south sulawesi (hikmah et al., 2019). the regency also enjoys easy access to research institutions and government agricultural programs that can potentially support the diffusion of improved varieties, cultivation techniques, and post-harvest technologies through collaborative innovation systems. on the other hand, farmers face multiple constraints, including land fragmentation, environmental risks in rain-fed agro-ecosystems, and climate-related uncertainty that significantly influence rice productivity and farm income (manzoor et al., 2025).

demographic challenges further worsen this situation; older farmers increasingly dominate the agricultural workers in maros regency, while youth interest and participation continue to decline, causing concerns regarding generational succession and long-term sector sustainability ((wibowo & alfarisy, 2024; haryati et al., 2024). these conditions highlight the urgency for extension interventions that are not only technically sound but also socially engaging and attractive for younger generations.

quick advances in information and communication technologies (ict) have opened new avenues to complement

traditional face-to-face extension through digital tools and guidance platforms. digital agriculture applications, mobile-based information systems, and online extension platforms are increasingly promoted as strategies for delivering timely, localised recommendations regarding climate, pests, market prices, and cultivation practices (world bank, 2020; manzoor et al., 2025). in indonesia, existing studies emphasize that digital agricultural innovations can improve productivity, decision-making, and market access; however, adoption remains uneven due to infrastructural, economic, and institutional barriers. empirical findings show that farmers benefit from digital advisory services, but limited internet connectivity, device ownership, and digital knowledge restrict inclusion, especially in rural areas (world bank, 2020; manzoor et al., 2025). consequently, extension strategies in regions such as maros must adopt a hybrid model that integrates interpersonal extension with ict-based approaches to ensure inclusivity and effectiveness across diverse farmer groups ((goeb et al., 2025b).

at the same time, effective extension strategies must take into account farmers' learning preferences, social networks, and local institutional structures. in many parts of indonesia, including south sulawesi, farmer groups and associations (kelompok tani and gapoktan) function as key platforms for knowledge exchange, collective action, and access to government programs. recent work on collaborative learning networks and community-based agricultural programs highlights the potential of group-based learning to strengthen social capital and economic empowerment among farmer groups (cai et al., 2023; mdiya et al., 2024; prastyanti et al., 2024; hasdiansyah et al., 2025).

alongside these group methods, individual outreach remains essential for diagnostic visits, personalized advice, and mentoring, while mass communication strategies such as radio programs, printed leaflets, videos, and public campaigns can expand reach and reinforce key messages. despite the availability of various approaches and methods, the success of agricultural extension in maros and elsewhere is conditioned by institutional support, resource availability, and the competencies of extension workers. studies on extension in indonesia show that extension agents often operate with limited operational budgets, high farmer-to-extension ratios, and uneven access to training on new technologies and digital

tools, all of which can constrain service quality and farmer satisfaction (nurjanah et al., 2024; dewi et al., 2025).

given these considerations, it becomes essential to conduct an in-depth analysis of extension approaches and methods applied in maros district in order to identify their strengths, limitations, and implications for farmer learning and technology adoption. insights from such an analysis can help align local extension practice with national priorities for digital agriculture, youth inclusion, and sustainable intensification, while also responding to the specific socio-ecological conditions of maros as a major rice-producing area in south sulawesi.

this article examine the methods and approaches used in agricultural extension in maros regency and talk about how these tactics can be improved to support sustainable agricultural development and increase farmers' capacities.

2.2. literature review

2.2.1 agricultural extension concepts and modern roles

agricultural extension has evolved from a traditional, top-down knowledge transfer model into a multidimensional service aimed at empowering rural communities through information dissemination, innovation diffusion, problem diagnosis, and decision support for sustainable agricultural development. modern extension frameworks emphasise the integration of advisory services, rural empowerment, capacity-building, and multi-actor collaboration among government, the private sector, research institutions, ngos, and farmer-led organisations ((davis & rasheed sulaiman, 2014; fao, 2020).this shift reflects the recognition that farming challenges cannot be solved solely through technology transfer but require systemic interventions that address knowledge, markets, risks, institutions, and socio-cultural contexts (anderson et al., 2024). recent global studies describe agricultural extension as a diverse system, comprising government agencies, private companies, ngos, community-based organizations, and digital service platforms (mudzielwana et al., 2025). extension workers are now responsible for more than just spreading new agricultural technology. they must also assist farmers in enhancing their problem-solving skills, forming partnerships, sharing knowledge, and adapting to climate risks (odongo et al., 2023). this shift is driven by the need for more

flexible, context-specific, and farmer-centered advisory services that align with rapid transformations in agricultural markets, sustainability imperatives, and digital technology adoption ((becerra encinales et al., 2024).

law no. 16/2006 on the agricultural extension system (aes) establishes the official framework for agricultural extension in indonesia. it says that extension services should help farmers become more powerful, increase productivity, and promote sustainable agriculture. as noted in the uploaded manuscript, ae is formally aligned with national priorities, such as the agricultural revitalization program (arp) 2025, which focuses on increasing the productivity of fourteen strategic commodities, including rice (lubis, 2012).

agricultural extension (ae) in maros regency has become increasingly central to the region's agrarian development path, particularly given its status as one of the key rice-producing areas in south sulawesi. as indicated by (nurman et al., 2022; saridewi & annisa, 2025) maros benefits from fertile lowland ecosystems that have long supported paddy cultivation and contributed substantially to regional food security. however, despite these favorable agroecological conditions, farmers in maros are simultaneously confronted with a range of structural and socioeconomic challenges that hinder productivity and long-term resilience. among the most pressing issues are land fragmentation, an aging farming population, declining interest in agriculture among youth, and increasing exposure to climate variability. these challenges have intensified over the past decade, shaping a complex environment in which traditional, technology-push models of extension are no longer adequate to meet farmers' evolving needs.

the growing complexity of these agricultural systems demands that extension officers expand their roles beyond the conventional function of disseminating technical information. contemporary ae practice in maros requires extension workers to act as educators who facilitate systematic learning processes, as intermediaries who connect farmers with research institutions, markets, and government programs, and as innovation brokers who encourage adaptive responses to local challenges (massimi et al., 2021). furthermore, as argued (sumandiyar et al., 2025), ae personnel today must also perform facilitative and mediating roles that enable collective problem-solving within farmer groups,

strengthen institutional capacity, and support inclusive participation particularly among marginalized smallholder households.

developing agricultural extension services in maros is critical to securing the long-term sustainability and competitiveness of the region's agricultural sector. strengthening the role of extension systems can accelerate the adoption of smart farming technologies, promote sustainable agricultural practices, and enhance farmers' resilience to environmental and climate-related challenges. to be effective, extension strategies should prioritize the empowerment of farmer groups by strengthening collective capacity, improving digital literacy, and ensuring timely and equitable access to relevant agricultural information and advisory services.

at the same time, encouraging youth participation in agriculture has become an urgent priority. several recent studies highlight a growing disengagement of young people from agricultural activities in the maros region (haryati et al., 2024).this trend poses a significant threat to the future of local agriculture, particularly in terms of labor availability, innovation capacity, and generational continuity. addressing this challenge requires the development of modern, youth-oriented extension approaches that leverage digital platforms, integrate entrepreneurship and agribusiness training, establish agricultural innovation centers, and create an enabling ecosystem for agritech startups.

by embracing these innovative and inclusive extension roles, digital agricultural extension in maros can be transformed into a strategic driver of rural development. such revitalized extension services will not only strengthen local farming systems and stimulate innovation but also contribute to long-term sustainability and resilience. ultimately, effective agricultural extension is essential for building a more prosperous future for farmers in maros and for reinforcing the region's strategic role in ensuring food security in south sulawesi.

2.2.2 extension approaches in rural and farmer group contexts

extension approaches encompass the guiding philosophies, organisational strategies, and delivery mechanisms through which advisory services are provided to farming communities. traditional models such as training and visit (t&v), farmer field schools (ffs), participatory extension, commodity-

oriented advisory, and value-chain-based services have shaped agricultural development for decades. however, contemporary extension systems increasingly adopt pluralistic, integrated, and digitally enabled approaches to respond to dynamic rural environments and evolving farmer needs ((ahmadi et al., 2025) in regions like the maros regency, characterised by diverse agroecosystems, varying levels of farmer capacity, and rapidly changing production challenges, choosing appropriate extension approaches is fundamental to improving local agricultural performance and resilience.

2.2.2.1 participatory and farmer-centered approaches

participatory approaches place farmers at the center of the learning process through joint problem identification, shared decision-making, and experiential learning. among these approaches, farmer field schools (ffs) are recognized as one of the most effective methodologies for rice-based systems. ffs encourages learning through field observation, experimentation, and group evaluation. this helps farmers understand how agroecological systems work instead of just following rules. evidence from various rice-growing regions in indonesia demonstrates that ffs enhances analytical skills, reduces excessive pesticide use, and encourages the adoption of climate-smart practices (jamil et al., 2023).

however, there are some significant issues, such as a lack of active participation from extension workers. this problem results in a heavy workload for each extension worker, as either the extension area they cover or the number of farmer groups they assist is substantial. therefore, the current situation requires agricultural extension workers to work hard despite the limited number of staff, and they must perform optimally to enhance their productivity.

in maros district, participatory approaches have gained increasing importance because of the area's diverse landscapes from irrigated lowlands to rainfed systems, which require localized solutions instead of one-size-fits-all national recommendations. as highlighted in the uploaded manuscript, participatory and demand-driven advisory processes ensure that extension interventions directly address farmers' needs, including challenges related to pest and disease pressures, water availability, and persistent post-

harvest losses. by fostering co-learning, these approaches strengthen farmers' problem-solving capacity and enhance the relevance of extension recommendations.

2.2.2.2 group-based extension in rural contexts

farmer groups (*kelompok tani*) and farmer group unions (*gapoktan*) are the backbone of indonesia's rural extension architecture. group-based approaches enable the organization of collective action, reduce transaction costs, promote peer-to-peer learning, and increase farmers' bargaining power in accessing inputs, information, and markets (baga et al., 2023). in maros, farmer groups are particularly influential in coordinating planting schedules, organizing training events, facilitating the distribution of government aid, and accelerating technology dissemination. however, this government support has not automatically led to the development of farmers. managing the institutional aspects of the agricultural system requires overcoming several challenges. the indonesian government recognizes the importance of farmer groups in developing the agricultural system, but the public does not.

this phenomenon is mainly because of the common belief that farmer groups are used only as political tools rather than truly providing economic benefits or improving farming productivity. this belief primarily arises from the perception that farmer groups are merely political tools, rather than genuinely contributing to economic benefits or enhancing farming productivity.

several studies show that strong, cohesive farmer groups can significantly improve the uptake of improved rice varieties, climate-smart agronomic practices, and digital tools for production management (hikmah et al., 2019; azhari et al., 2025). well-functioning groups also play an important role in supporting mechanization services, collective marketing, and strengthening linkages with extension officers and local institutions.

2.2.2.3 systemic and innovation-system approaches

the modern extension approach in maros regency employs the agricultural innovation systems (ais) framework, which emphasizes that innovation arises from interactions among various actors, including research institutions, extension agencies, universities, local extension centers, and farmer networks. this

approach is particularly relevant to the maros regency, given its geographic proximity to research centers and agricultural universities, which creates chances for collaborative trials, adaptive research, and joint scaling of innovations. the study suggests that improving ais linkages in maros can enhance technology diffusion, improve feedback loops between farmers and researchers, and ensure that innovations are embedded within local socio-technical contexts (alim et al., 2024).

the enhancement of agricultural adoption lies in a profound reform of extension systems. such reform should focus on design and operational models that are more inclusive, adaptive, and acutely attuned to the complex realities of farmers in the maros regency (becerra-encinales et al., 2024). by incorporating systemic thinking, the ais-based extension transforms extension from a linear technology-transfer model into a dynamic, network-driven, and context-responsive process that fosters sustainable agricultural development.

2.2. 3 performance of the agricultural extension center (bpp) maros

the agricultural extension center maros (balai penyuluhan pertanian bpp) acts as the main institution responsible for coordinating, implementing, and evaluating agricultural extension activities at the sub-district level. its performance is important because it influences the effectiveness of extension services, particularly in regions such as the maros regency, which is one of the key rice-producing areas in south sulawesi. as an operational hub, the bpp ensures that various extension programs ranging from farmer training to technology transfer to group facilitation to institutional capacity building are carried out systematically and reach their intended beneficiaries. the effectiveness of bpp operations has a direct effect on farmers' knowledge, their use of modern farming methods, and overall improvements in food security and productivity. studies conducted in indonesia and other asian countries consistently show that well-functioning extension centers significantly accelerate the diffusion of innovation, strengthen farmer decision-making capacity, and improve the performance of farmer groups (nurman et al., 2022; azhari et al., 2025).

research focusing on south sulawesi also highlights that the responsiveness and competence of extension officers, supported by strong bpp management, contribute to better

monitoring, problem-solving, and mentoring processes for rice farmer groups (azhari et al., 2025). similar trends can be seen in southeast asia, where localized extension institutions are necessary for supporting agricultural transformation, improving farmers' ability to adapt, and encouraging sustainable farming systems (baul et al., 2024).

these results align with studies across southeast and south asia, which highlight that the performance of local extension institutions is a decisive factor in facilitating digital extension initiatives, enhancing farmer learning processes, and promoting rural transformation ((tripathi & ahmed, 2023; baul et al., 2024). collectively, the experience in maros reflects a broader regional pattern: effective extension centres serve not only as administrative hubs but also as catalysts for innovation diffusion, capacity development, and the long-term resilience of farming communities.

2.2.3.1 institutional functions and mandates of bpp

bpps serve as the administrative and technical backbone of local extension systems. their mandates include (i) planning and coordinating agricultural extension programmes, (ii) managing farmer databases through systems such as simluhtan, (iii) supervising extension officers (ppl), (iv) facilitating training, field schools, and demonstration plots, (v) supporting the strengthening of farmer groups and farmer group unions (gapoktan), and (vi) conducting monitoring and evaluation of field programmes (kementerian pertanian republik indonesia., 2021).these roles are consistent with international frameworks, such as the global forum for rural advisory services (gfras), which emphasize the need for decentralized, data-driven, and inclusive extension institutions to support large and diverse rural populations. as an intermediary organisation, bpps also link farmers with research institutions, value chain actors, and digital advisory platforms, mirroring institutional models observed in vietnam, india, and the philippines ((singh et al., 2023;dinh et al., 2023).

2.2.4. bpp performance indicators in supporting rice farmer groups

evaluating bpp performance requires assessing multiple dimensions, including the quality and frequency of extension activities, the relevance of training materials to agroecological

conditions, extension worker competence and workload, farmer satisfaction, adoption rates of recommended practices, institutional strengthening of farmer groups, and the integration of digital monitoring and advisory tools (zikri. et al., 2021). these indicators reflect international evaluation frameworks used in indonesia, where the performance of the extension system strongly correlates with farmer productivity and innovation adoption(ragasa & mazunda, 2018).

in maros district, the bpp has been instrumental in disseminating improved rice varieties, balanced fertilisation practices, irrigation scheduling techniques, and post-harvest innovations consistent with findings from rice-producing regions in bangladesh and vietnam, where strong local extension institutions accelerate technology uptake (dinh et al., 2023). given maros's contribution to south sulawesi's rice production, improvements in bpp performance are directly associated with sustained productivity and more resilient farmer groups.

2.2.5 challenges faced by bpp maros

despite institutional strengths, bpp maros faces several operational constraints. the ageing extension workforce limits field-based support and mirrors trends documented across indonesia, where shortages of younger extension personnel pose long-term sustainability risks (indraningsih, ashari, syahyuti, anugrah, suharyono, saptana, iswariyadi, agustian, purwantini, ariani, et al., 2023).the frequency and quality of farmer engagement are diminished by the insufficient extension worker-to-farmer ratio, a problem also noted in south asian and african extension systems. despite compelling evidence that, when properly integrated, digital advisory systems greatly enhance farmer decision-making, some staff members' lack of digital literacy impedes the efficient use of new ict-based tools (fabregas et al., 2019). budgetary constraints further limit bpp's capacity to carry out regular monitoring and field demonstrations.

the regeneration of farmer groups is still hindered by low youth participation in agriculture, a problem that has been extensively documented in maros regency and throughout the indonesia-pacific region. moreover, climate variability and environmental risks necessitate that extension institutions provide more dynamic and responsive advisory services(suriani et al., 2023;

haryati et al., 2024).

2.2.6 research gap synthesis

the reviewed literature highlights strong scholarly attention toward digital agricultural extension and participatory learning. however, few studies examine the adaptation of extension approaches and methods specifically within micro-regional contexts such as the maros district. localized evidence regarding district-level extension practices, farmer perceptions, and institutional challenges is still sparse.

therefore, this study fills the gap by analyzing how extension approaches and methods are applied in maros district, examining their alignment with socio-ecological and demographic conditions, and identifying the necessary institutional improvements for future extension performance in the region.

2.3 research methods

this study adopted a qualitative descriptive design, an ideal approach for delving into the intricate social processes surrounding extension strategies, farmer groups, and learning environments for farmers (cottrell et al., 2018).

by utilising a multisystemic approach model, we can integrate various perspectives in our data analysis, leading to a more comprehensive and accurate understanding of the subject. this approach involves a thorough examination of the key concepts related to the research topic (cottrell et al., 2018). this design enables richer insights and a deeper understanding of these crucial agricultural extension dynamics by giving contextual analysis and interpretive understanding precedence over simple quantitative generalisation.

the study utilized both secondary and primary data to ensure a comprehensive analysis. secondary data consisted of peer-reviewed articles published between 2020–2025, government policy documents, agricultural extension guidelines, and bps statistics on agricultural production in maros regency. these sources provided essential contextual and conceptual foundations for the research. primary data were gathered through interviews with agricultural extension workers, offering direct insights into extension practices and field-level realities. in-depth interviews enabled the

capture of nuanced perspectives and experiential knowledge that may not appear in written sources. field observations were also conducted to examine real-time conditions, allowing the researcher to identify contextual factors and dynamics that might remain hidden in interviews or documentary analysis.

these sources are regarded as credible for analysing patterns, trends, and institutional frameworks in agricultural extension (world bank, 2020; tripathi & ahmed, 2023).

2.3.1 data analysis technique

the data that has been collected is analysed using a triangulation and interaction model. in the first, we employed qualitative thematic analysis to interpret and integrate insights from the collected literature. following the analytical procedures suggested by creswell and poth (2021), the analysis began with initial open coding to identify key concepts and recurring statements across the data corpus.

the coded information was then clustered into broader thematic categories, including extension approaches, participatory and farmer-centred methods, digital transformation processes, institutional capacities, and operational challenges within extension systems. subsequently, thematic synthesis was performed by linking the extracted themes to established theoretical perspectives and national agricultural extension policy frameworks. this step enabled a coherent interpretation of how current extension dynamics align with or diverge from policy expectations and international best practices.

to enhance the credibility and reliability of findings, data triangulation was conducted by cross-validating evidence derived from peer-reviewed journals, government policy documents, and statistical reports. this triangulation process strengthened the robustness of the thematic interpretations and ensured that conclusions were grounded in multiple independent sources. (sumandiyar et al., 2025).

2.4 results and discussion

the Indonesian government's 2025-2029 plan aims to increase agricultural productivity to meet the growing year-round demand for food and achieve self-sufficiency, thereby reducing reliance on food imports. this increasingly requires agrarian extension workers to play their role and be optimally present to achieve this goal.

according to the head of the agriculture extension centre in the maros region, the extension workers are pivotal agents of change, bringing the government's agricultural development strategies to life. they play a crucial role in disseminating vital information about innovative farming practices and effectively promote the ministry of agriculture's cutting-edge digital extension methods. agricultural extension officers (penyuluh pertanian lapangan – ppl) in maros regency play a pivotal role in empowering farmers, strengthening institutions, and disseminating technology. their roles are aligned with the pedoman penyuluhan pertanian (kementerian pertanian ri, 2021) and the national extension system under law no. 16/2006.

2.4.1 maros' approach to agricultural extension development

the results showed that both district-specific priorities and national policy directions are influencing the strategic transformation of agricultural extension in maros regency. interviews with extension officers and analysis of regional planning documents show that maros places strong emphasis on institutional strengthening, particularly through the upgrading of balai penyuluhan pertanian (bpp) into fully operational kostratani hubs. these hubs serve as centres for managing farmer data, spreading technology, and coordinating field activities. this result aligns with previous studies showing that well-organised extension institutions enhance farmer learning and accelerate technology adoption, particularly in rice-based systems (faure et al., 2022; syahyuti, 2021). (izmi et al., 2021; indraningsih et al., 2023; tapi et al., 2024).

the study also found that the district prioritizes the professionalization and continuous development of extension human resources. extension workers in maros receive structured training, mentoring, and competency upgrades that reflect the ministry of agriculture's broader agenda of improving extension quality through the application of competency standards (skkni). respondents

emphasized the importance of these efforts in improving their confidence and technical readiness in the field. this corroborates earlier research indicating that extension worker competence is one of the strongest predictors of farmer engagement and successful extension outcomes (davis & rasheed sulaiman, 2014; ragasa & mazunda, 2018).

digitalization emerged as another key strategic direction. maros has integrated systems such as simluhtan, digital reporting tools, and collaborative programs with polbangtan gowa and brmp to strengthen data-driven decision-making. extension officers highlighted that these tools improve coordination and reduce administrative delays. this observation supports studies demonstrating that digital extension platforms enhance information flow and enable farmers to make faster and more informed management decisions (aker et al., 2016; klerkx et al., 2022).

furthermore, the district's strategy incorporates youth and agripreneurship development, particularly through the yess program. respondents noted that youth-targeted activities not only support farmer regeneration but also stimulate local innovation and entrepreneurship. this aligns with evidence from (mikkelsen & chapagain, 2023), which demonstrates that youth-inclusive extension approaches significantly contribute to rural economic diversification and long-term sectoral sustainability. maros integrates climate-smart and sustainable agriculture into its extension strategy.

field data revealed that extension workers increasingly incorporate themes such as water management, resilient varieties, and low-emission practices into their training sessions. this reflects broader findings in the literature that climate-informed extension enhances farmers' adaptive capacity and resilience, particularly in regions vulnerable to environmental (hansen et al., 2019; aryal et al., 2020).

overall, the findings demonstrate that maros regency adopts a comprehensive and forward-looking strategy to strengthen its agricultural extension system. the district presents itself as a model of modern agricultural extension practice in indonesia by coordinating local implementation with national reforms, while addressing the engagement of farmer groups, digital transformation, institutional capacity, and climate resilience.

2.4.1.1 digitalisation and the changing roles of extension workers

the results of this study reveal that agricultural extension workers in maros regency are undergoing a significant shift in their roles and responsibilities as digital transformation accelerates across the Indonesian agricultural sector. traditionally, extension workers have operated primarily as field educators who transmit technical knowledge and agricultural innovations through direct contact with farmer groups. however, as digital tools and information systems become more integrated into agricultural practices, their role has evolved to encompass facilitation, mediation, technical guidance, digital literacy support, and data-driven advisory functions. this expanding role reflects national and regional trends in which rural advisory systems are increasingly required to align with digital agriculture initiatives.

routine interaction with farmers remains one of the most fundamental responsibilities of extension workers. the study found that regular visits allow extension workers to provide timely information, understand emerging challenges, and respond to the dynamic conditions of maros's rice-based farming systems. this finding is strongly supported by recent Indonesian research showing that communication intensity frequency, duration, and quality of extension-worker contact significantly improve farmer learning outcomes and productivity (mardiharini et al., 2023). a similar pattern was documented in manokwari, where the integration of ICT tools enhanced farmers' access to real-time agronomic information; however, the positive effects still depended on the presence of extension workers who could support the interpretation and application of digital content (tapi et al., 2024) these findings confirm that, in the digital era, physical interaction remains essential but works best when complemented by digital communication tools.

in the interviews, some farmers highlight a major finding: the continued use of group-based extension methods often fails to meet the needs and preferences of farmers. many farmers face time constraints due to household responsibilities or off-farm work, making group attendance difficult. this challenge is not unique to maros; various studies across Indonesia note that farmer heterogeneity, differences in cropping calendars, land size, income levels, and digital capabilities, reduce the effectiveness of traditional

kelompok tani-based (farmer group-based) learning (apriliani, 2024).

farmers increasingly prefer individualized extension support because it offers personalized guidance tailored to their specific conditions, whether related to soil quality, input availability, or market challenges. this preference for individualized learning echoes findings from several southeast asian countries, where household-level advisory systems have increased both adoption rates and farmer satisfaction. for example, studies in laos and cambodia demonstrate that one-on-one extension interactions lead to faster uptake of improved seed varieties, integrated pest management practices, and climate-smart technologies (apriliani, 2024).

the digitalization of agricultural services introduces new opportunities for extension workers to bridge information gaps. farmers in maros reported increasingly using smartphones, social media, and instant messaging platforms such as whatsapp to obtain agricultural information. extension workers who actively leverage these channels are able to communicate more efficiently, disseminate market updates, share pest outbreak warnings, and provide fertilizer application reminders. the 2025 national review of digital agricultural extension emphasizes that digital platforms can significantly reduce the burden on extension workers by improving information speed, accuracy, and coverage, particularly in regions with limited numbers of extension personnel (patria, 2025). moreover, the introduction of digital applications such as “petani apps” has shown that extension workers play a crucial mediating role in helping farmers adopt new technologies, overcome digital literacy barriers, and interpret agronomic recommendations (prayuda, 2024).

the study reveals several persistent barriers that limit the effectiveness of digital extension in maros regency. first, many extension workers demonstrated varying levels of digital literacy, often lacking the confidence or technical skills needed to use mobile-based platforms effectively. this problem is widely documented in indonesia’s rural advisory system, where uneven ict training and limited institutional support slow the adoption of digital tools among extension agents. second, time constraints emerged as a notable issue. farmers reported that extension workers often spent only 20–30 minutes in the field due to heavy workloads or secondary employment. these short visits limit the potential for meaningful engagement, especially in cases where farmers require in-depth

problem-solving support. evidence from indonesia's cyber extension adoption research similarly indicates that extension workers frequently lack adequate time for field visits due to administrative burdens and staff shortages (apriliani, 2024).

a striking finding from this study is that the performance of extension workers tends to improve significantly during government-led evaluation or selection periods. during these times, extension workers increase field visits, prepare demonstration plots, enhance communication efforts, and actively seek farmer feedback. this pattern is consistent with national and regional evidence showing that performance-based evaluation systems, especially those linked to recognition or incentives, temporarily elevate motivation and service quality (triguna, suharno, & adhi, 2022). however, reliance on external incentives may pose sustainability concerns, as performance gains often diminish once evaluations conclude.

table 1. shows the themes derived from document review.

theme / code	description	field results	references (indonesia & se asia)
1. role expansion in the digital era.	extension workers are shifting from conventional knowledge transfer to digital facilitation, ict support, and real-time advisory functions.	extension workers in maros increasingly combine field visits with whatsapp messages, digital advisories, and online communication.	(mardiharini et al., 2023).
2. communication intensity matters	frequent, high-quality interactions influence farmer decision-making and the adoption of innovations.	farmers reported better understanding and faster responses when extension workers maintain weekly or on-demand contact.	(patria, 2025); (alhassan, a.m, et al., 2023).
3. ineffectiveness of farmer group-based extension	farmer group meetings are often poorly attended and fail to accommodate diverse schedules and farmer needs.	farmers cannot attend because of off-farm work, household duties; information gaps occur.	(apriliani, 2024)
4. farmer preference for individualized advisory	farmers prefer personalised guidance over group instruction, as it more effectively contributes to their success.	direct consultations are preferred; farmers report better clarity and trust in individualized guidance.	(savitri & rafani, 2024)
5. ict as a complementary tool	digital platforms enhance information speed, dissemination, and emergency communication.	farmers rely on whatsapp for pest alerts, rainfall warnings, and fertilizer schedules. extension workers send quick updates.	(apriliani, 2024) (kamal & bangladesh, 2023).

6. digital literacy gaps	extension workers have varying levels of ict proficiency, which limits their adoption of digital tools.	some extension workers struggle with apps, online reporting, and data entry.	(prayuda, 2024).
7. limited visit duration (workload constraints)	heavy workloads, administrative duties, and secondary jobs reduce time for field visits.	farmers report visits lasting only 20–30 minutes; insufficient for in-depth problem solving.	(yulia dinda et al., 2024).
8. incentive-driven performance peaks	extension performance improves during government-led evaluations due to incentives and competition.	extension workers become more active, prepare demonstration plots, and increase visits during evaluation periods.	(triguna et al., 2022 (goeb et al., 2025)
9. hybrid extension model needed	integrating digital and traditional methods enhances service delivery effectiveness..	farmers rely on ict for quick updates but prefer face-to-face support for complex problems.	(sumandiyar et al., 2025)

according to the head of the agriculture extension centre in the maros region, the extension workers are pivotal agents of change, bringing the government's agricultural development strategies to life. they play a crucial role in disseminating vital information about innovative farming practices and effectively promote the ministry of agriculture's cutting-edge digital extension methods. agricultural extension officers (penyuluh pertanian lapangan – ppl) in maros regency play a pivotal role in empowering farmers, strengthening institutions, and disseminating technology

overall, the results demonstrate that the digital transformation of agricultural extension in maros requires a more flexible and integrated approach. extension workers are no longer simply conveyors of information; they are digital facilitators, data interpreters, and adaptive problem solvers. to optimize their effectiveness, it is essential to strengthen digital literacy, improve institutional support for ict use, reduce administrative burdens, and design incentive systems that sustain motivation beyond evaluation periods. a hybrid extension model, combining individualized advisory services, ict-based communication, and contextually relevant group activities, offers the most promising pathway for aligning extension services with the diverse needs of maros's farming communities in the digital age.

2.4.1.2 strengthening farmer groups (poktan)

the strengthening of farmer groups (poktan) and farmer group unions (gapoktan) represents a central pillar of the agricultural extension strategy in maros regency. the district adopts a systematic and institution-focused approach, recognizing that well-functioning farmer organisations serve as critical intermediaries between smallholder farmers and broader institutional, financial, and market systems. extension officers play a pivotal role by facilitating legal registration and verification, assisting groups in obtaining formal recognition that enables access to government programs. they also support the continuous updating of farmer profiles through simluhtan, ensuring data accuracy for targeting beneficiaries and monitoring program performance.

capacity-building initiatives constitute another essential component. extension workers provide structured leadership and financial governance training, equipping group leaders with managerial, organizational, and record-keeping competencies needed for transparent and accountable group management. strengthening collective action mechanisms, such as joint marketing schemes, pooled procurement of agricultural inputs, and coordinated planting, further enhances group efficiency and reduces production and transaction costs. additionally, farmer groups are actively assisted in securing access to credit schemes (e.g., kur), seed distribution programs, and agricultural machinery support, which enables members to improve productivity and mitigate input risks. these findings are consistent with recent scholarship, which emphasizes the critical contribution of farmer organizations to improving smallholder bargaining power, strengthening market integration, and enhancing resilience (aku et al., 2018; borby et al., 2023; luis & teng, 2023). empirical studies in southeast asia similarly demonstrate that strong producer groups facilitate economies of scale, reduce information asymmetries, and increase adoption of improved technologies and digital tools (luis & teng, 2023). in the indonesian context, recent research highlights that effective poktan and gapoktan governance leads to better targeting of government assistance and improves accountability in extension service delivery (dharmawan, muljono, hapsari, et al., 2020).

in maros, the consolidation of poktan and gapoktan not only strengthens farmer agency but also improves the overall

performance of district extension institutions. robust farmer organizations ensure that public programs are delivered efficiently, beneficiaries are well-targeted, and agricultural innovations reach the intended farming communities in a timely and equitable manner (lesmana & imaningtias, 2018).

2.4.2 stakeholder collaboration and the role of farmers' groups in agricultural development

the analysis confirms that efforts to strengthen the agricultural sector in maros regency are closely tied to the performance of farmers' groups and the quality of stakeholder collaboration. in line with spatial studies on agricultural production in south sulawesi, which show that improved management, information systems, and land-use planning significantly raise crop output and rural income (irsan et al., 2020) farmers' groups in maros function as key entry points for productivity-oriented interventions.

farmers' groups in maros act not only as beneficiaries but also as strategic stakeholders that co-manage rice intensification programs, extension activities, and access to inputs and markets. this pattern mirrors broader evidence from indonesia and other developing countries, where group-based collective action and farmer-based organisations are consistently associated with higher productivity, efficiency, and improved market access for smallholders (baga et al., 2023; burhan, 2023).

the stakeholder landscape around agricultural development in maros involves actors at multiple levels: village farmer groups (poktan), farmer group unions (gapoktan), sub-district agricultural extension centres, district government agencies, the private sector, and sometimes ngos. similar multi-level configurations are described in agricultural innovation system studies from south africa and other regions, where research institutions, extension services, farmer organisations, and private actors jointly shape innovation trajectories and rural development outcomes (sinah & oladele, 2016; zwane, 2020; maryono et al., 2024).

stakeholder mapping of farmers' groups in maros used principles from stakeholder analysis and the influence–interest matrix. the results show: (i) a small set of highly influential “key players” (e.g., strong gapoktan leaders and extension agencies); (ii) groups with high interest but limited influence that require empowerment; and (iii) peripheral actors with low visibility in

decision-making. this approach is consistent with recent applications of influence–interest mapping in indonesian agri-food systems (effendi et al., 2024; muzaqi et al., 2025) and follows the broader typology of stakeholder analysis proposed by (reed et al., 2009), which emphasizes identifying stakeholders, differentiating their roles, and analyzing their relationships.

these findings underscore that stakeholder collaboration is not merely an “add-on” but a central governance mechanism for agricultural development in maros regency. recent reviews of multi-stakeholder partnerships (msps) in agriculture show that well-designed platforms can align heterogeneous interests, improve information flows along value chains, and enhance farmers’ bargaining power, although they also face challenges of power asymmetry and coordination costs (maryono et al., 2024; ewijk et al., 2024).

evidence from ethiopia and desira-funded msp initiatives further indicates that state-initiated or donor-supported platforms can strengthen agricultural innovation system capacity when they deliberately link research, extension, farmer groups, and the private sector (seifu et al., 2022; s. drimie et al., 2023). in this context, positioning farmers’ groups in maros as core stakeholders is consistent with global findings that group membership and collective marketing arrangements contribute to higher technical efficiency, better prices, and more resilient participation in value chains (branca et al., 2022; бага et al., 2023).

for maros, this implies that policies should not treat poktan and gapoktan merely as administrative targets for subsidy distribution, but as partners in co-designing extension programs, piloting innovations, and monitoring implementation outcomes. the use of stakeholder analysis and the influence–interest matrix in this study also aligns with recent indonesian and international work that applies these tools to agricultural extension, livestock supply chains, and natural resource governance (muzaqi et al., 2025).

by systematically distinguishing between stakeholders with high influence and high interest (key players), those with strong influence but low interest (context setters), high-interest but low-influence groups (subjects), and low-interest, low-influence actors (crowd), local governments in maros can prioritise engagement strategies, tailor communication, and design capacity-building interventions that are politically and socially realistic. overall, the

results suggest that strengthening stakeholder collaboration, particularly between farmers' groups, extension services, and district-level planning units, can help maros regency move beyond project-based interventions toward more integrated, innovation-oriented agricultural development. this is consistent with broader arguments that robust agricultural innovation systems require dense linkages among research, extension, farmers, and input–output markets, supported by inclusive governance arrangements (fao, 2020; shaliza et al., 2025).

the policy and practice in maros mean that future programs should explicitly embed stakeholder mapping, farmers' group empowerment, and multi-stakeholder platforms into extension strategies, rather than treating them as optional or purely consultative exercises.

2.4.3 conceptual framework

the conceptual framework guiding this study illustrates how agricultural extension workers in maros regency adapt to evolving approaches and methods within the broader landscape of digital transformation in indonesia's agricultural sector. as national agricultural and digitalization policies increasingly emphasize the integration of information and communication technologies, extension systems are required to move beyond conventional face-to-face interactions and incorporate digital tools into their service delivery processes. this transition includes the use of mobile-based platforms, social media, online advisory systems, and data-driven decision-support tools to enhance the reach, timeliness, and relevance of extension services. consequently, agricultural extension operates within a multi-layered environment in which traditional interpersonal communication, such as field visits and group meetings, must be strategically combined with digital mechanisms to effectively address the diverse capacities, preferences, and constraints of farming communities.

within this framework, extension workers function as critical intermediaries who facilitate the translation of digital information into practical knowledge that is understandable and applicable at the farm level. their adaptive capacity is influenced by access to digital infrastructure, digital literacy, institutional support, and farmers' readiness to engage with technology-enabled services. the framework further recognizes that digital agricultural extension does

not merely involve technology adoption but also entails changes in communication patterns, knowledge exchange processes, and farmer participation. by integrating both human-centered and technology-driven dimensions, the conceptual framework captures the dynamic interaction between policy direction, extension practices, and farmer engagement. this holistic perspective provides a foundation for analyzing how digital transformation reshapes extension service delivery and contributes to the development and empowerment of farmer groups in maros regency.

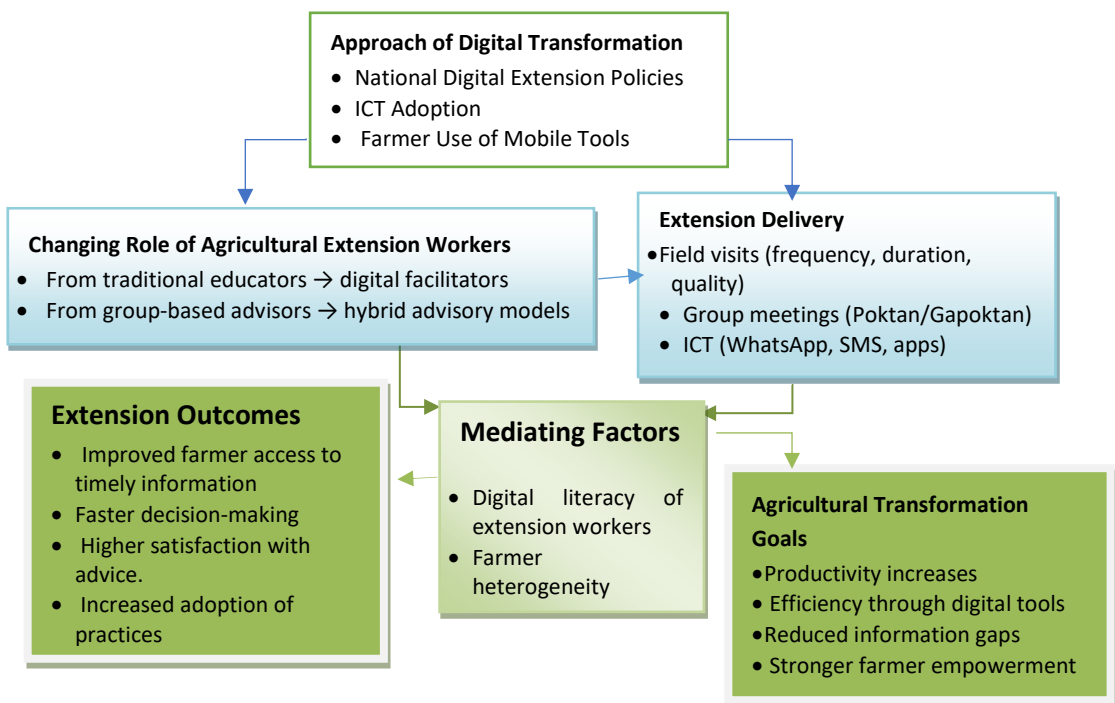


fig 1. conceptual framework model.

2.5 discussion

the results of this study show that the agricultural extension system in maros regency is undergoing substantial transformation driven by institutional reforms, digitalization, farmer groups' collaboration, and evolving farmer needs. the transformation reflects a broader national shift within indonesia's agricultural extension system (aes), which aims to modernise rural extension services to support national goals for productivity, food security, and climate resilience. in maros, these dynamics manifest through strengthened extension institutions (bpp and kostratani), enhanced human resource development, increased use of digital tools, and adaptive changes in extension approaches. these dynamics are shown through better human resource development, increased adoption of digital tools, and adaptive adjustments in extension strategies. together, these transformations reshape the role of extension workers from traditional communicators to multidimensional facilitators integrating digital and interpersonal advisory methods.

a major contribution of this study is its illumination of how district-level extension strategies operationalize national policy directions, especially those related to digital transformation, farmer database integration, climate-smart agriculture, and youth engagement. the upgrading of balai penyuluhan pertanian (bpp) into kostratani hubs demonstrates institutional strengthening consistent with national policies outlined in the ministry of agriculture's pedoman penyuluhan pertanian (2021). these hubs have become centers of data management, extension coordination, and local-level monitoring. the results affirm findings from (munalula & mpundu, 2025; indraningsih et al. 2023) who emphasise that decentralized and well-governed extension institutions accelerate knowledge dissemination and technology adoption, particularly in rice-based farming systems. digitalization emerged as one of the most transformative factors shaping extension practice in maros. the integration of simluhtan, digital reporting tools, and ict-based communication platforms improves efficiency, reduces administrative delays, and enhances coordination among extension workers.

these findings align with research by (aker et al., 2016; klerkx et al., 2022) which shows that digital tools in extension systems reduce information asymmetries, improve timeliness of advisories, and support evidence-based decision-making. however, consistent

with national assessments (fabregas et al., 2019; patria, 2025) shows that digital adoption is uneven due to differing levels of digital literacy among extension workers. digital competence remains a limiting factor that can slow the uptake of ict-based tools unless targeted capacity-building programmes are implemented.

the study also highlights the changing nature of extension workers and farmer groups. in the digital era, extension workers increasingly combine face-to-face communication with mobile-based interactions via whatsapp, sms alerts, and other social media platforms. this hybrid model enhances flexibility, allows real-time communication, and provides farmers with more frequent updates, particularly regarding pest outbreaks, rainfall forecasts, or fertiliser application schedules. the results support the argument by (mardiharini et al., 2023) that communication intensity frequency, duration, and quality of interaction remains a major determinant of extension effectiveness, even when digital tools are involved. yet, while ict improves outreach, it does not replace the contextual value of direct field interaction. many farmers in maros continue to rely heavily on face-to-face guidance, especially for complex agronomic decision-making related to pests, water management, and soil problems. these findings echo studies by (kamal & bangladesh, 2023; apriliani, 2024) which show that personalized advisory services outperform group-based extension in terms of adoption rates, farmer satisfaction, and understanding of new technologies. a key insight from this study is that group-based extension—long considered the backbone of indonesia's extension system is becoming less effective for certain categories of farmers. diverse schedules, off-farm employment, household responsibilities, and differing learning preferences reduce attendance at kelompok tani meetings. therefore, extension strategies must strategically shift toward individualized advisory services, particularly in areas with high farmer heterogeneity.

institutional roles of farmer groups (poktan) and farmer group unions (gapoktan) remain central to extension delivery in maros. the study shows that farmer organizations serve as primary channels for distributing government support programs, coordinating planting schedules, and facilitating group-based learning. strengthening these organizations through leadership training, organisational capacity-building, and access to c(seifu et al., 2022)redit schemes aligns with earlier research by(dharmawanet al., 2020; бага et al.,

2023) emphasises that well-governed farmer groups improve program targeting, adoption speed, and transparency of extension services. the ability of extension workers to enhance group governance has strong implications for local agricultural development, especially as maros seeks to sustain its position as a major rice producer in south sulawesi. the results also reveal critical challenges. time constraints among extension workers limit the depth of field engagement. many extension workers spend only 20–30 minutes per visit due to heavy workloads, administrative responsibilities, and, in some cases, secondary employment. these findings are consistent with (yulia dinda puspaningtyas et al., 2024), who noted that excessive administrative burdens reduce time available for farmer mentoring, thereby limiting extension impact. another challenge is that performance tends to improve only during evaluation periods. while external incentives stimulate activity, the lack of sustained motivation outside evaluation cycles raises concerns about long-term consistency. this reflects patterns observed by (triguna, suharno, & kilat adhi, 2022) who documented similar incentive-driven performance peaks among extension agents in indonesia.

stakeholder collaboration plays a critical role in ensuring the success of extension programs. this study confirms that maros relies on multi-stakeholder networks involving bpp, gapoktan, district government agencies, private agribusinesses, ngos, and research institutions. such collaboration aligns with the agricultural innovation systems (ais) approach, which argues that innovation emerges from interactions among diverse actors (seifu et al., 2022; anderson et al., 2024). the influence–interest mapping applied in this study identifies which stakeholders serve as key players, which function as context setters, and which require empowerment to enhance participation. recent works in indonesia (effendi et al., 2024; muzaqi et al., 2025) affirm the importance of mapping stakeholder relationships to improve governance and ensure more inclusive policy implementation.

climate-smart and sustainable agriculture considerations are increasingly evident in extension practice. extension workers in maros incorporate climate-adaptive strategies such as improved irrigation, balanced fertilization, stress-tolerant varieties, and environmentally friendly pest management. these practices reflect global calls for climate-informed extension services that build

smallholder resilience to weather variability and climate risks (hansen et al., 2019; aryal et al., 2020). the integration of these topics confirms the district's commitment to aligning extension practices with long-term sustainability goals and national food system resilience strategies.

a demographic challenge low youth participation in agriculture emerged prominently. extension workers report that young people are generally disinterested in farming, a trend also noted by (suriani et al., 2023; wibowo & alfarisy, 2024). programs such as yess are beginning to address this issue by promoting agripreneurship, digital tools, and innovation-based farming among rural youth. however, more inclusive, sustained, and attractive youth-focused interventions are needed to ensure generational continuity and stimulate innovation in the sector.

collectively, the findings show that the extension system in maros is transitioning toward a hybrid model that integrates digital tools, individualized advisory services, strengthened farmer groups, multi-stakeholder governance, and climate-smart agriculture. this transformation is essential for supporting productivity, sustainability, and farmer resilience within the rapidly changing agricultural landscape in south sulawesi.

2.6 policy implications

enhance the digital skills of extension workers through targeted ict training, digital literacy programs, and ongoing professional development to fully integrate digital tools into extension services.

shift toward a hybrid extension model: policies should support a balanced combination of digital advisories, individualised extension visits, and selective group learning where appropriate.

institutionalize multi-stakeholder platforms: regular coordination between farmer groups, bpp, local government, research institutions, and private actors should be formalized to enhance innovation diffusion and program targeting.

enhance farmer group governance: leadership, financial management, and organizational skills training will strengthen poktan and gapoktan performance and improve program accountability.

develop youth-centred agricultural programs: agritech incubators, digital agriculture training, and youth-focused

entrepreneurship initiatives are needed to address generational challenges.

integrate climate-smart extension: policies should mainstream climate-adaptive practices into extension curricula, demonstration plots, and digital advisories to enhance resilience.

2.7 conclusion and recommendations

this study demonstrates that agricultural extension in maros regency is undergoing a critical transformation shaped by institutional reforms, digitalization, evolving farmer preferences, and multi-stakeholder collaboration. extension workers are transitioning from traditional knowledge transmitters to hybrid facilitators who integrate face-to-face mentoring, digital communication tools, and data-driven advisory services. despite these advances, persistent challenges, such as limited digital literacy, workload constraints, inconsistent performance motivation, and the reduced effectiveness of group-based extension, continue to hinder optimal service delivery. strengthening farmer groups (poktan/gapoktan), enhancing institutional governance, and mainstreaming climate-smart practices are essential for sustaining progress.

moving forward, several recommendations emerge.

1. extension workers require continuous professional development in digital competencies, problem-solving, and youth engagement strategies to match the increasing complexity of agricultural systems.
2. maros regency should adopt a long-term hybrid extension model that strategically balances individualized advisory services with ict-supported communication and selective group activities.
3. the government should institutionalize multi-stakeholder platforms to enhance collaboration among bpp, research institutions, private agribusinesses, and farmer organizations.
4. reducing administrative burdens through streamlined digital reporting systems would free extension workers to spend more time in the field.
5. youth-focused programs—integrating agripreneurship, technology, and innovation—are vital to address generational decline in farming participation.
6. climate-smart agriculture must be embedded into all extension curricula, demonstration plots, and digital advisory tools to build long-term resilience.

collectively, these recommendations underscore the need for a modern, inclusive, and adaptable extension system that can drive sustained agricultural development and enhance farmer welfare in maros regency.