The Role of Agricultural Extension in Farmers' Technology Adoption for Sustainable Agricultural Practices in Davao Oriental, Philippines

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ABSTRACT

Agricultural extension services are a key driver of technology adoption among farmers and help raise their productivity and ensure agricultural sustainability. This paper is a review of the systems, regulations and procedures that encompass agricultural extension in Davao Oriental and the implications for the adoption of technology. The results indicate that the Agricultural Training Institute (ATI) and private sector initiatives complement each other in providing extension services. Rural extension programs have developed with the guiding of policy and financing programs, such as the Agriculture and Fisheries Extension (AFE) Strategic Plan 2023-2028. There are, however, obstacles to the mainstreaming of ICT use in the agricultural sector including, but not limited to, financial constraints, low levels of digital literacy, and socio-cultural norms against the use of the technology by agriculturalists. This paper highlights the necessity for more effective extension modalities such as digital and ICT-based methods, participatory learning tools and financial support mechanisms for promoting technology transfer. cooperative, community-led strategies, also have community-based origins and a role, and include peers, are constructed to increase sharing of knowledge and confidence in new ways of agricultural technologies. Reasoning on the prevailing constraints and the enhancement of the extension strategies, the farmers in Davao Oriental would now be able to develop a long-term sustainability and resiliency in agriculture.

Keywords: Agricultural extension, technology adoption, sustainable agriculture, Davao Oriental, extension strategies.

INTRODUCTION

Agricultural extension services have been, for a decade, a pillar of most rural development, especially in agrarian economies where farming is the mainstay. They are institutions that help in transferring of agro-innovations/technology from research institutions to farmers and they serve as the bridge linking the scientific research and the grassroots application (Davis et al., 2012). By means of organized instruction, on-farm demonstrations, and advice, extension provides farmers with improved knowledge, productivity, and sustainability of farming. Extension services have been vital to food security, climate resilience and rural empowerment in many developing countries like the Philippines (Kassem et al., 2023).

In the Philippines, agricultural extension has transformed dramatically from top-down, supply-driven system to more participatory and technology-enabled set-ups. The government, through the ATI, spearheads the

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provision of decentralized and digitalized extension services. The ATI's Agriculture and Fisheries Extension Strategic Plan (2023–2028) focuses on the integration of digital technologies, agripreneurship, and the decentralization of services as a strategy to build the resilience and enhance the competitiveness of the sector (ATI Central Office, 2023). This strategic shift is particularly important in places, like Davao Oriental, where agriculture is a key part of the local economy and farmers have become more exposed to environmental and market stress.

Even if there are strategic direction and policy support, there is still an erratic and slow pace in the use of technology by the Filipino farmers. This is apparent in the low adoption of climate-resilient crops, organic farming practices, and ICT-based advisory services in Davao Oriental. Obstacles, such as insufficient funding, computer illiteracy, socio-cultural opposition, and non-integrated service delivery, prevent widespread technology use (Dissanayake et al., 2020; Briones et al., 2021). Though there are pockets of successful adoption sprinkled like coffee tree son Mt. Hamiguitan among co beneficiary farmers these are the exception rather than the tendencies than the normal (Bacong et al., 2024).

A major challenge is to reduce the mismatch between the use of technologies and local requirements and farmer capacities. National programmes are usually devoid of contextually sensitive local factors that makes it challenging for introduced technologies to be implemented and more importantly sustained. Furthermore, lack of farmers participation in planning and evaluating extension activities reduces the relevance and ownership of interventions (Chambers, 1994). Therefore, although policies and programmes exist, the means to ensure efficacious and in technology transfer need to be investigated and improved.

The motivation for this study arises out of the pressure on agro- innovation trends to inter-mesh with the farmer adoption in Davao Oriental. The province is confronted with new set of challenges with regard to climate variability, deteriorating soil fertility, and fluctuating market prices making technology appropriate mechanization not only an economic but also an ecological and social necessity (Sarita & Inutan, 2025). It entails rethinking ways in which agricultural extension can serve as a carrier of knowledge and also as a vehicle for participatory, site-specific, and sustainable development.

This paper filled the gap on the research on the effectiveness of AE services in the promotion of technology adoption towards sustainable agriculture in Davao Oriental. Although national extension systems are studied extensively in the literature, there are limited analyses on local dynamics, community uptake and social technical drivers of adoption at the provincial level (Gonzales & Magcale-Macandog, 2020). Furthermore, there has been little empirical evidence on the interactions of digital tools, community-based approaches and financial mechanisms and how this contributes to the efficacy of extension services.

The study aimed to systematically review effects of agricultural extension on technology development in smallholder agriculture-based livelihoods farmers' adoption of Davao Oriental. Primarily, it aims to analyze the nature and modes of extension services in the province, factors impacting positively or negatively on technology adoption, the extent to which digital and participatory facilitation have been combined and resource, and evidence-based policy recommendations to improve extension strategies for sustainable agricultural development.

The research uses a systematic review approach to achieve the aims and draws upon peer-reviewed journal papers, government and policy reports, case studies and policy documents in the last decade. The words "Vulnerability," "Resilience," "agricultural extension," "technology adoption," "sustainable agriculture," "Davao Oriental" were also included in sourcing literature. A thematic analysis was then used to collectively summarize the findings across data sources and inform qualitative and quantitative assessment of the efficacy of the extension services in the province contribution to wider debate on agricultural transformation in the Philippines.

This paper focuses on Davao Oriental, providing a case study from which lessons can be drawn. It demonstrates the successes and the shortcomings of existing extension approaches as well as provides

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pragmatic pathways to scaling-up best practices. Critical is that the study brings attention to local farmers, cooperatives and extension workers and others who are all too often marginal to the design of policy, yet sit at the heart of policy implementation. In the end, this study suggests that if properly funded, context-relevant, participatory extension is implemented in Davao Oriental, it can be a triggering point for sustainable development. In the process it further challenges the notion that agricultural modernization is simply a matter of new technology introduction, and instead build systems of learning, cooperation and trust that enable farmers to innovate and adapt in the face of change.

OBJECTIVES

1. To evaluate the efficacy of agricultural extension services in the promotion of sustainable agriculture practices and technology transfer for smallholder farmers in Davao Oriental.
2. To assess the contribution of indigenous knowledge systems and their complementation with modern agricultural technologies in enhancing productivity and resilience in farming populations.
3. To assess the adoption and extent of use of digital tools, ICT platforms and precision agriculture technologies in improving decision-making, input-use efficiency and environmental performance.
4. To understand how participatory methods such as FRCs and community-based training affect the fit, adaptability, and adoption of new technologies.
5. To determine the knowledge-deficits and the impact of targeted capacity building programs in overcoming them and facilitating the adoption of sustainable farming practices.
6. To develop context-specific policy and program options to strengthen the agricultural extension system in technology transfer, making it inclusive, efficient, sustainable.

METHODOLOGY

This research is a systematic review that employs a step-by-step procedure in the examination of the contribution of agricultural extension in farmers' uptake of technologies in achieving sustainable agriculture. The stages of the review process include literature identification, data extraction, and synthesis. For thorough and unbiased coverage, peer reviewed journal articles, government reports and other policy documents were obtained from reputable sources. For this purpose, search terms like agricultural extension, technology adoption, sustainable agriculture, Davao oriental, and extension strategies were used in the review of previous works. Inclusion criteria source of literature Studies published in the last ten years focusing on the structure, policy, constraints and prospects of agricultural extension and technology transfer. Grey literature, such as, fed from the Agricultural Training Institute (ATI) and Philippine government agencies, was also considered as the methods to capture regional extension patterns. Discussion Upon identification of relevant literature, data extraction was performed to extract significant themes, trends and results related to agricultural extension in Davao Oriental. The data retrieved were regarding extension services models, digital innovations, policy backing, and farmer's adaptability to new technologies.

The studies were classified according to areas addressed, as government support extension, private sectors participation, economic instruments and social and cultural elements that are against technology globalization. Results: Case studies and policy documents were analysed to generate narrative about the context, and quantifiable benefits of extension were reported in summary tables. The results were quantitative were presented on measurable benefits to productivity and incomes. The review attempted to take a balanced approach to the strengths and weaknesses of extension efforts by triangulating across several data sources.

In the synthesis down-streaming phase, thematic analysis was carried out to combine results from different sources. Key discussion points were summarized, namely about digital and ICT extension platforms, participatory learning, and the importance of financial and policy support for technology dissemination. The topics discussed hereon are: "Agricultural Extension Services in Davao Oriental," "Farmers' Adoption of Technology in Davao Oriental," "Sustainable Agriculture Practices and Prisoners of Extension Services

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Adoption," "Impact of Agricultural Extension on Farmers' Productivity and Performance and Societal Uptake." A Review of Literature on Extension Approaches to Technology Transfer", paper Presented at the 2003 Congress of the Assembly, International Association of Agricultural Economists, Durban: "Determinants of Experimental Farmers' Willingness to Participate" in the Agricultural Extension "Influence of TOT Mode on exhibitions.

The review also looked at community-based interventions like cooperatives and peer learning networks to evaluate other ways in which knowledge was exchanged and also explore the adoption of technology. The study as well admitted to some limitations, primarily on the lack and accessibility of empirical data on actual extension programs in Davao Oriental. Yet, by examining many different sources, this synthesis provides comprehensive conclusions about AE as well as specific suggestions for increasing technology adoption and achieving sustainable agriculture in the region.

DISCUSSIONS

Agricultural Extension Services in Davao Oriental

The extension services in Davao Oriental play a crucial role in disseminating technologies, and in improving farmers' knowledge and practices in order to achieve higher levels of productivity, sustainability, and agricultural development. The include training schemes, workshops and field demonstrations, where farmers are trained in new agricultural and sustainable techniques. The key specific objective is to provide farmers with the requisite knowledge and tools for achieving an increase in crop productivity and yield, in an environmentally sustainable way (Davis et al., 2012; Gonzales & Magcale Macandog, 2020).

The organization of these extension services includes the intervention of government and private sector. The government, particularly through the Agricultural Training Institute (ATI), offers a cornerstone function, which is Farmer's training and information provision. ATI has been identified as the lead agency for e-Extension, a tool that uses electronic media to relay information for the development of a modernized agriculture (ATI Davao, n.d.; Briones et al., 2023). For profit institutions and cooperatives reciprocate by providing specialized education and granting credit while sharing a joint responsibility to improve the agriculture (Alzate, 2013). The extension work is successful thanks to policies and funding. The ATI's Agriculture and Fisheries Extension (AFE) Strategic Plan for 2023–2028 is guided by thrusts that include efficient production, enhanced competitiveness through agripreneurship, and attaining nourishment among Filipino farm and fisher families. This plan also emphasizes the use of ICT to enhance farmers' access to information (ATI Central Office, 2023). Moreover, municipal programs like this and regional efforts such as the Province-led Agriculture and Fisheries Extension System also aim to empower provinces to make even more localised agricultural development (ATI Davao Region, 2023).

A few intervention programs are now in place in Davao Oriental to help the farmers. Cooperative development has supported this through micro-financing of the technologies — hybrid rice, hybrid corn and eggplant production, for example. These programs have in fact effectively contributed to increases in the farmers' income and productivity of crops proving the effectiveness of properly developed policies with financial assistance, case after case (Alzate, 2013; Bayani and Corpus, 2024).

Partnerships were formed between government agencies and the private sector for a strengthened agricultural extension system in Davao Oriental. Through cooperation of these players, it guarantees that the farmers are supported in all scales, such as in terms of technical support and financial lending, supporting the sustainable farming activities (Bacong et al., 2024; Agro-Eco Philippines, 2020).

Additionally, digital technology has improved the manner in which information is transmitted to farmers through extension services. Farmers may also access information through the internet, the electronic virtual extension (e-Extension) services, which offer updated training materials that makes learning easier and faster (Fabregas et al., 2019; ATI Davao, n.d.).

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The extension work has been able to run due to both government and private funding support. Funds for training programs, infrastructure projects, and technology adoption projects are appropriated to enable farmers to operate according to modern farming methods (Sarita & Inutan, 2025; ATI Davao Region, 2023). Government policies, financing schemes, and partnership approaches have enhanced agricultural extension service in Davao Oriental(). By raising the bar and applying best practices consistently, they provide for environmentally sustainable agriculture and farming community development in the province (Mwangi, 2024; Mendoza & Quiton, 2024).

Technology Adoption among Farmers in Davao Oriental

Adoption of new agricultural innovations by farmers is determined by a multitude of factors. These range from personal factors (age, education level, experience of farming) to external factors such as credit and extension services. It is important to know these factors in order to facilitate the development of sustainable agriculture in the area (Mwangi, 2024). Other factors that influence the acceptance of technology are the characteristics of the farmers. “The choice you make is telling lots of things about you,” Prof. Geruso said, pointing to the stylistic or cultural associations of certain inputs and resources, as well as age and comfort with technology — young farmers may be more open to trying new tools than older ones, for example. Furthermore, more educated people have an easier time grasping and adopting new practices. Practice in farming is significant as older farmers may stick to old methods and younger ones more willing to test new ways (Kassem et al., 2023). Social, economic, and institutional constraints such as willingness to adopt new technologies by farmers, among others, affect potential adoption of new technologies.

Financial constraints can limit the possibility of investing in modern equipment or practices. Drift towards traditional views and beliefs on culture may cause some farmers to prefer the practice of what have been handed down the generations from their forefathers therefore being resistant to change (Gonzales & Magcale-Macandog, 2020). Access to knowledge and supportive services is essential for the uptake of technology. Farmers that have frequent access to agricultural extension services are also more aware of and adopt new technologies. These services offer them training and knowledge resources for them to learn about the benefits and ways of implementing innovative ways of production (Fabregas et al., 2019).

Adoption rates are also influenced by the characteristics of the technologies themselves. Farmers would not be likely to adopt a new technology if it is seen as too complex or not compatible with the existing farming practices. On the other hand, technologies which are cost-effective, user friendly and have visible advantages are more readily adopted by the majority of farmers (Douthwaite et al., 2003). Efforts to strengthen technology transfer in Davao Oriental may involve improving access and delivery of extension services. With the provision of more localized and individualized support, extension workers can target farmers' specific concerns and needs and make new technologies more accessible and meaningful (Boz & Akbay, 2005).

There is also a strong role that may be played by financial instruments such as micro-finance programs. Affordable credit access provided to farmers on the part of these program prepare them to invest on the new technologies that they may not afford leading to its adoption and eventually increasing the productivity 50 (Sarita & Inutan, 2025). On the other hand, community based approaches such as farmers’ cooperatives, peer learning and/or farmer to farmer support could help in increasing the uptake of technologies. Farmers see other farmers making it work, and they are more willing to switch themselves, potentially. Such social networks can function as sharing and bonding portals and form trust in emerging technologies (Chambers, 1994).

Sustainable Agricultural Practices and their Adoption through Extension Services

Promotion of sustainable farming practices has now been widely recognized as a top-priority for environmental soundness and livelihoods of farmers. Climate-smart and regenerative agricultural practices like agroforestry, intercropping and organic farming are being implemented to deal with problems like soil

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degredation and climate change. Such approaches are intended to maximise productivity and protect the natural resource base (FAO, 2021). Agroforestry, the inclusion of trees in farming systems, has been proved to enhance soil fertility and generate new sources of income from timber and fruit. Intercropping, multiple crops grown together, decreases pest infestations while maximizing land use. Organic farming doesn't use synthetic chemicals, which makes for healthier soils and produce. Such practices would lead to a more sustainable agricultural system in the area (Pretty et al., 2018). Extension agents are key in their efforts to disseminate these sustainable practices. They are also the medium of communication between research establishments and farmers, guiding the dissemination of information and techniques. Extension workers teach and persuade farmers to understand and adopt new skills through training sessions, workshops and field demos. Their ongoing backing allows farmers to properly execute these practices (Swanson & Rajalahti, 2010). The capacity of extension services increases with setting up of training centres. For example the DOT declaration of the Davao Oriental Development Centre completed launched on 2024, February, a center for Remedial horticulture. It is well-facilitated based learning centre which imparts skill-based training to farmers so that they can also practice the sustainable farming. The overall agro-extension is supported by such infrastructure system in the province (Davao Oriental Provincial Information Office, n.d.).

Working with organizations such as Agro-Eco Philippines has also helped. These partnerships are squarely aimed at shifting farmers towards agroecological and organic regenerative practices. By promoting local knowledge and sustainable practices, they educate farmers to be more self-reliant and ecologically sound. These efforts expand the resources available to extension personnel and farmers (AgroEco Philippines, 2020).

There are shining examples in the region of case studies. In Mt. Hamiguitan's buffer zone, for instance, smallholder coffee growers were also practicing sustainable coffee farming, which resulted in increased coffee productivity and quality. With the training and backing from the extension services, these farmers have improved their production capabilities and responded to the problems posed by climate change. This successful outcome demonstrates the impact of tailored extension programs (Bacong et al., 2024). Training of AEWs on way soybean production in Davao region. By empowering AEWs with the right skills and information, they can more effectively facilitate farmers' adoption of sustainable approaches. This is not only beneficial to increase crop yield, but also helps in meeting the region's aspiration to minimize dependency for importable produce (ATI RTC XI, 2024). Collective efforts of extension workers, training centers, and the like have greatly influenced the adoption of sustainable agricultural practices in Davao Oriental. As a result, such practices have fostered better yields, environmental sustainability as well as increased income to farmers. To sustain and improve these gains, further impetus and innovation are needed in extension services (Rasul, 2022).

Impact of Agricultural Extension on Farmers' Productivity and Income

Agricultural extension is an important tool with which farmers are equipped or motivated to improve their productivity and income. These include vocational training, workshops, and new agricultural technology, which are all designed to enhance agricultural production. With the use of these better methods, farmers can enjoy higher yield and produce better quality products, which generates them high income and an enhanced standard of living (Anderson & Feder, 2004).

Researchers have found out "statistically significant influences" of extension services on farm production and living. For example, enrolment in agricultural extension activities has been linked to substantial increases in crop yields and per capita household expenditure, pointing to increased economic welfare among farmers (Davis et al., 2012). The results highlight the critical role of extension services in agricultural development and poverty alleviation. Farmers in extension access group are compared with those in non-extension access group and differences in productivity and income are compared. Farmers that engage with extension services tend to achieve higher yields and higher profitability compared to those that don't. For instance, a study in Kenya reported that farmers who accessed the devolved agricultural extension

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services increased their crop incomes by KSh. 5,165.87/ acre for non-users (Mwangi 2024). This shows the beneficial role of extension on on investment in agriculture products (particularly fresh crop) in browse; end up such livestock like skin and hide 92 forest outcomes. There are significant enduring advantages of ongoing extension assistance. Continued interaction with extension agents helps the farmers to keep abreast of new trends, learns to cope with these changes and introduce new technologies. Over the long term, this sustained assistance leads to higher farm productivity, better household incomes and greater food security. Further, this has helped to build the resilience of farming communities to manage stresses such as climate change and market shocks (Swanson and Rajalahti, 2010). The availability of extension services is related to the decision making of the farmers. Properly advised, farmers will more readily embrace sustainable practices, buy quality inputs and diversify their farming activities. Such informed decision-making results in efficient resource use and higher return on investment and enhances farm productivity (Feder et al., 2004). Extension services also will typically help you access markets by supplying information about quality standards, prices, and market trends. Such market linkage enable farmers to demand better returns for their produce making them economically secured. Extension programs using information and communication technologies (ICTs), have also been popular in reaching farmers with valuable information in time data, thus enhancing productivity and income even more (Fabregas et al., 2019).

Note that extension services can be effective depending on quality, mode of delivery and farmers' characteristics among others. Customizing extension programs to be relevant to various farmer subgroups, taking into account for instance gender, level of education and farm size, will increase their effectiveness. For example, interventions that focus on gender-based constraints have been demonstrated to have positive effects on the agricultural performance of women (Lambrecht et al., 2016). Extension services contribute positively to increased farm productivity and income generation to farmers'. These services enable farmers to continue receiving technical support, training and access to resources, which allows them to innovate, overcome obstacles and make a step-change towards more sustainable livelihoods. Therefore, investing in functional extension systems is critical to agricultural development and poverty reduction (World Bank, 2007).

Enhancing Agricultural Extension Strategies for Effective Technology Transfer

Agricultural extension services educate and assist farmers in adopting new technologies that contribute to increased productivity and sustainability. In Davao Oriental, improvements in extension approaches can increase efficiency in technology transfer and increased penetration rate of modern farm technologies. To realize this, extension programs need to implement service delivery best practices, incorporate digital resources (Federfeld et al., 2008), and deploy strategies to meet local demand (Anderson & Feder, 2004).

One of the effective methods towards extension service delivery is that of the participatory approach, initiative on the part of the farmers to be party to learning. Such simplification of methods help the farmers in comprehension and adoption of new technologies/resulting in improved productivity and farm management. Farmers are more likely to take active decisions to replace in traditional methods and adopt new innovations when they are part of demonstrations, field trials and participative training programmes. Crop extension programs should be adapted to address specific farm sustainability challenges, to ensure their support is helpful and practical (Kassem et al., 2023). The use of digital tools and information and communication technologies (ICT) into extension services has significantly facilitated sharing of information in agriculture. ICT-based extension services, including mobile applications, online training packages and digital advisory platforms, enable farmers to obtain real-time information on farming practices, weather events and market prices. In the Philippines, the Department of Agriculture has launched e-governance programs to help farmers through digital tools for the easy access of agricultural information (Briones et al., 2023). In Davao Oriental, the Agriculture Training Institute (ATI) has come up with digital materials for use in extension services. Farmers now have been provided with multimedia-based, distance learning technologies, virtual training and web-based learning materials. These are also helpful in making the extension services more efficient, especially to the farmers in remote communities who may not be provided

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with the appropriate in-person technical trainings (ATI Davao, n.d.). But for digital expansion to be successful, efforts to boost digital literacy among farmers as well as extensionists (Ragasa et al., 2016). Developing the capacity of extension services is the main challenge to enhance agricultural extension services in Davao Oriental. Scheduled training programmes will help in upgraded extension workers up to date with new developments skills and information to instruct farmers properly. Trained extension officers can respond effectively to farmers' needs, and thus build trust and adoption of new methods and technologies (Rasmira & Gandasari, 2023). Furthermore, it will increase relevance to the expressed needs of the farmers which, in itself, will improve the level of participation. A further important measure is to increase community participation and collaboration between government authorities, academia and private entities. Cooperation can also contribute to more financial resources, know-how and access to better agricultural technologies. Farmer and research institution linkage has resulted in faster uptake of climate-smart and sustainable principles in many successful instances agricultural techniques (Douthwaite et al., 2003). Monitoring and evaluation are equally important to make the extension effective. By evaluating how extension services have improved the productivity of the farmers, weaknesses in the system can be highlighted and improved upon. A feedback process in which farmers communicate about their experiences and problems will contribute to the improvement of future extension activities (Leeuwis, 2004). Continuous monitoring and mechanisms should be put in place to see to it that extension work is based on the needs of farmers for the province of Davao Oriental. A strengthened agricultural extension approach involves use of both participatory learning, digital technologies, capacity development, integrated approach and periodic review. Through these initiatives, technology transfer in Davao Oriental can be enhanced with better productivity and income level of farmers. By investing in effective and innovative extension services sustainable farming will be adopted and benefit farmers and the environment alike (Swanson & Rajalahti, 2010).

FINDING

Agricultural extension is central to the process of technology transfer to farmers, leading to higher outputs and sustainable farming. The infusion of indigenous wisdom with modern approaches has been crucial in Davao Oriental. For example, a study of smallholder coffee farmers on the Mt Hamiguitan Bufferzone in the Philippines showed that the farmers have adopted sustainable practices and technologies (agroforestry systems and organic farming) to enhance productivity and environmental sustainability. Remarkably, women are participating widely in these efforts and are engaged both in farming activities and in decision making, which makes the community more resilient to the impact of climate change (Bacong et al., 2024).

Technology has become even more widespread through the creation of specialized training centers. One of such is the Davao Oriental Development Centre (DODC) which we can be a center of excellence for farmers technology transfer with modern equipment and facilities. This center provides holistic training programs on contemporary farm technologies which aim to improve farmers' skills and promote sustainability (Provincial Government of Davao Oriental, 2023). Collaborations between NGOs and local villages as well have served as a tremendous support. The Mindanao Baptist Rural Life Center (MBRLC), which, for instance, designed and disseminated agroforestry systems for small holders. These mechanisms have succeeded to promote sustainable agricultural practices, enhance soil fertility and increase crop productivity. The MBRLC's strategy reflects a focus on community engagement and development, which is indispensable for successful transfer of new technologies (Tacio, 1993). The role of digital tools and information and communication technology (ICT), as an indispensable part of the contemporary agricultural extension services, is unquestionable. The use of ICT promotes instant information sharing that allows farmers to gain access to current information on agriculture practices, weather, and market trends. As a result of this digital evolution, decision-making is better, and efficiency has improved in agricultural work (Wikipedia, 2025). This resource use efficiency has been improved by adoption of precision agriculture technologies. "Through the use of variable-rate application (VRA) technology, farmers can precisely apply the amounts of inputs, such as water and fertilisers, required to help improve efficiency and minimising the impact on the environment. It is observed from empirical data that VRA improves input use efficiency and can result in higher yields (Wikipedia,2025).

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Community-based participatory methods have been useful in addressing local issues and in encouraging technology use. For example, Farmer Research Committees (FRCs) represent local farmers inside the research process to enable that the technologies introduced are adjusted to local needs and context. The participation approach provides new interpretations that are more relevant, as well as the greater acceptance, of new technologies, and may also enhance their adoption rate (Wikipedia, 2025). Analysis of training need has helped in identifying the incomplete technical know and how of farmers. In the Davao mill area, such assessments have resulted in specialized training programs that would enable farms to adopt better practices and at the same time higher productivity. Such targeted trainings provide different platforms Matching farmer trainee needs with training content such programs have facilitated the adoption of new technologies and sustainable technologies (Gonzales et al., 2020).

Sustainable agriculture was adopted successfully in Davao Oriental through the combination of blending traditional and modern technologies, direct training programs hosted by training centers, partnerships between NGOs and the local demographic, digital tools, precision agriculture technologies, participatory research trends, and the training of farmers and local leaders. Together, they have increased farmers' ability to use new technologies, and farmers have become more productive and sustainable in this part of the agricultural sector.

CONCLUSION

Extension services provided by the local governments in Davao Oriental also have been instrumental in the province's agricultural development by introducing environment-friendly practices and new farming technologies. The extension workers have facilitated the transfer of practical skills and technical know-how to the farmers with interventions such as hands-on training programs, farming demonstrations and locally organized study sessions. The positive things associated with the uptake of BBN strategies, have resulted in increased productivity, resource use efficiency and ecological stability of farming system in provinces (Mwangi, 2024; Mendoza & Quiton, 2024).

The use of digital technologies in agricultural extension work, especially with e-Extension, has also further changed how information is acquired and used by farmers. Tools based on ICT have made the systems able to provide up-to-the-minute information about market trends, pest and disease outbreaks, weather forecast, and practices in crop production and are crucial for effective agricultural decision making (Fabregas et al., 2019; Briones et al., 2023). These developments have also contributed to greater access to extension services, including for populations in remote and under-served agriculture communities that were previously excluded by conventional delivery mechanisms.

Institutional partnerships have also been crucial. The mutual cooperation between the government departments, academic institutions, the non -government organizations (NGOs) and the cooperatives have led to the formation of a multi – stakeholders system for agricultural development. The Agricultural Training Institute (ATI) has been a key player in guiding the training programs and local universities and private actors have contributed the technical know-how and resources. These have contributed to the diversity and relevance of the extension services in Davao Oriental (ATI RTC XI, 2024; Agro-Eco Philippines, 2020).

Yet systemic and structural challenges persist to curtail the fuller actualization of technology penetration in this region. Cost constraints continue to be a challenge, particularly for smallholder famers without access to convenient credit or social support programs for purchasing modern inputs and equipment. Socio-cultural determinant, including a conservative outlook and low tolerance of risk are also cited as restraining adoption of unknown technological tools (Gonzales & Magcale-Macandog, 2020; Kassem et al., 2023). In addition, differences in digital literacy and infrastructure exacerbate inequality between early adopters and those that are left behind.

A more well-rounded, farmer-centered extension service delivery approach is necessary to overcome these challenges. De-centralising agricultural technologies, designing with -- rather than for -- farmers, and

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targeting assistance based on demographic and geographical profiles can enhance uptake. For example, technologies need to be targeted to upland or lowland ecosystems; or irrigated or rainfed conditions production practices (Douthwaite et al., 2003). Secondly, broadening out the spaces for participation – e.g. Farmer Research Committees and peer led knowledge exchanges – may increase farmer ownership of innovations and contribute to reinforcing community learning (Chambers, 1994).

The financial instruments should also be redesigned to make them more inclusive and bankable. Sustainable farming investment can benefit from the blending of finance options such as microcredit schemes, cooperative-run revolving funds, and government-supported input subsidies, to address the initial capital constraint for farmers to embrace new practice. Community-based infrastructure investment like training hubs, seed banks, and rural ICT centers investments over longer period can also serve to strengthen technology adoption and rural resilience (Bayani & Corpus, 2024; Sarita & Inutan, 2025).

Last, but not the least, for long-term sustainability, agricultural extension needs to take a systems approach, balancing the set of climate smart with principles of regenerative agriculture and gender responsive approaches. Emphasizing women farmers, youth, and indigenous communities in extension planning could unleash untapped potential among the farming community. Extension systems too need to adopt feedback loops, data gathering, adjustment and evidence-based programming to be responsive to changing challenges, such as those presented by climate variability and market shocks (Lambrecht et al., 2016; Davis et al., 2012).

The agricultural extension system in Davao Oriental has achieved success, but there is need to constantly innovate, provide institutional support, and build capacity of communities to ensure its sustainability. A forward-looking extension inclusive, resilient, and sustainable framework will be critical to reinventing the province's agri-food sector from something that is fairly effective to something that is holding the checkerboard of practices into the 21st Century.

RECOMMENDATION

There is thus a need for a more holistic approach that would reinforce the authority of agricultural extension services in enhance of technology adoption and sustainable agricultural products in Davao Oriental. This included focusing on digital infrastructure, strengthening participatory frameworks, offering financial incentives and developing institutional and civic capacity.

Modern extension systems require digital tools to be effective, but internet access in many Davao Oriental communities is spotty at best. This ICT-based digital divide constrains access and effectiveness of ICT-based agri-advisory platforms (e.g., mobile apps, online webinars, and market information systems) (Fabregas et al., 2019; Briones et al., 2023). The government with the help of the telecommunications outfits should give attention to improvement of broadband connections in rural and farflung barangays. Investments by the government in digital infrastructure, specifically by the Department of Information and Communication Technology (DICT) and the Department of Agriculture (DA) can help ensure that our marginalized farmers have equal access to timely information (ATI Davao Region, 2023). But the digi-tools won't be useful unless farmers and agricultural extension staff are also trained to use them. Handing over digital literacy training to extension programs will ensure that the potential of ICTs is fully exploited. This entails hands-on practice for: mobile-based advisory apps, social media for market information gathering and digital communication platform (Rasmira & Gandasari, 2023).

It is necessary to upskill the Agricultural Extension Workers (AEWs) continuously for their relevance and efficiency in knowledge dissemination (ATI RTC XI, 2024). Participatory tools, such as Farmer Research Committees (FRCs), peer learning and farmer-led demonstrations, may be scaled-up to empower communities and to contextualize interventions for differing agro-ecological conditions (Chambers, 1994; Dissanayake et al., 2022). These models enhance farmers engagement and confidence with new technology, as it has been proven that adoption is more successful if innovation is co-created and contextually adapted

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(Gonzales & Magcale-Macandog, 2020). Community-based information exchange networks also contribute to the sustainability of the diffusion of innovation outside of the formal extension mechanism.

Successful adoption of innovations could be increased through partnerships between government agencies, state universities and private agribusiness, including NGOs. Local educational institutions like Davao Oriental State University (DOrSU) must have a support collaboration program with ATI and cooperatives on co-generating location specific agricultural technologies. Such partnerships have the potential to facilitate the pooling of technical resources, the scaling up of training, and the development of co-creations that address farmers' real world problems (Sarita & Inutan, 2025). One of the major barriers to technology uptake is smallholder farmers' low purchasing power. Availability of credit via micro-finance institutions like Land Bank and local cooperatives will enable the farmers to invest in quality seeds, mechanization and precision farming technologies Bayani & Corpus, 2024).

Government subsides and grants also should extend to such farmers who are interested in sustained practices including organic farming, climate resilient cropping and conservation agriculture (Sokolov et al., 2020). Such incentives had to be designed to stimulate long-term and incremental sustainability efforts ability to function without assistance indefinitely. Strong Monitoring and Evaluation (M&E) systems need to be institutionalized as a way forward to ensure that extension systems are responsive and results-based. participatory mobile surveys, and crowd-communication tools. Trials, community scorecards that can monitor the uptake and influence of technologies on yield, income and environmental outcomes (Davis et al., 2012). Routine evaluations will also pinpoint areas not implemented, allowing for program improvement.

Women have a significant role in agriculture in Davao Oriental, however they continue to confront systemic issues that help restrict their access to extension services, credit, and land. Extension services should be sensitive to gender in their training nature, timing and delivery so as to accommodate women farmers (Lambrecht et al., 2016). Increasing women's membership in cooperatives, leadership and adoption of technology trials have a positive impact on community-based adoption and household food security.

We need to change agricultural extension in the region to focus on climate-smart and regenerative practices that maintain soil health, water and biodiversity in the long term. Sustainable practices such as agroforestry, integrated pest management (IPM), intercropping, and organic soil amendments should be emphasized in training modules and support programs (Bacong et al., 2024). Supporting and promoting local seed saving and other strategies of participatory plant breeding helps reduce reliance on outside input suppliers and build agroecological resilience, as well (Agro-Eco Philippines, 2020).

Leveraging these approaches— digital inclusion, participatory learning, financial support, institutional collaboration, and sustainability focused interventions—agricultural extension in Davao Oriental can be accelerated as an effective platform in driving inclusive, climate- resilient, and innovation-driven rural development.

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