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Community-Based Digital Extension to Strengthen Local Food Resilience under Climate Uncertainty

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Abstract

Climate uncertainty poses challenges to agricultural sustainability and local food security, especially in rural areas that still rely on traditional counseling. This study aims to analyze the effectiveness of community-based digital extension in strengthening food security through increasing access to climate information and farmers' adaptive capabilities. The research was conducted in Parigi Moutong Regency, Central Sulawesi, which has the characteristics of an agrarian community, is affected by climate change, and has the potential to apply digital technology. Using a mixed methods approach, the study involved 80 farmer households as survey respondents and 5 key informants consisting of agricultural extension workers, community leaders, farmer group leaders, and farmers who are active users of the digital platform. Quantitative data was analyzed with descriptive statistics and paired t-tests, while qualitative data were processed through thematic analysis. The results showed that the use of community-based digital extension platforms increased farmers' access to climate information, improved adaptive farming practices, and improved household food diversity scores within three months of implementation. This study concludes that the integration of digital extension in the community agribusiness system in Parigi Moutong is an effective strategy to strengthen adaptive and sustainable local food security in the midst of climate uncertainty.

Keywords: Community-Based, Digital Extension, Food Resilience, Climate Uncertaint.

INTRODUCTION

Climate uncertainty is one of the most serious challenges in modern agricultural systems because it has a direct impact on land productivity, food security, and socio-economic sustainability of rural communities. Changes in rainfall patterns, extreme temperatures, and hydrometeorological disasters disrupt the planting cycle and reduce crop yields, especially in tropical agrarian regions such as Central Sulawesi. According to research Habib-ur-Rahman et al., (2022), unexpected climate variability results in a 20 percent decrease in agricultural productivity in the tropical regions of Southeast Asia (Habib-ur-Rahman et al., 2022). In this context, the community-based agricultural extension system is the spearhead of adaptation because it serves as a bridge between scientific knowledge and local practice. However, the transformation of extension to a digital form still faces technological literacy obstacles and limitations in rural infrastructure. The limitations of conventional counseling that are still face-to-face have created an information gap between extension workers and farmers, especially in the face of rapid climate change dynamics. Study by Maulu et al., (2021) shows that traditional agricultural extension often fails to reach small farmer groups due to limited extension workers and wide range of work areas (Maulu et al., 2021). Meanwhile, digital extension is starting to show great potential in improving communication efficiency, access to weather data, and agricultural technology updates (Singh et al., 2023). However, there has not been much research that examines the integration between digital systems and community-based approaches in the context of local food security in climate-sensitive tropical areas such as Parigi Moutong.

Previous empirical studies have highlighted many digital technology innovations in agriculture, but few have examined how local communities can become key actors in digital extension systems. For example Steinke et al., (2022) emphasizing the importance of community participation in the design of digital systems so that interventions are more relevant and sustainable (Steinke et al., 2022). However, most of the research was conducted in developed countries with better technological infrastructure conditions, so it did not fully describe the context of Indonesia's agrarian region. This creates a research gap on how community-based digital counseling can play a role in strengthening local food security amid increasing climate uncertainty. In addition, research by Apriani (2022) revealed that the effectiveness of the digital extension system is greatly influenced by social factors such as trust, community solidarity, and local adaptive capacity (Apriani, 2023). In agrarian societies, horizontal communication between farmers has an important role in spreading innovation and strengthening collective resilience. Therefore, it is necessary to approach counseling that not only focuses on technology, but also pays attention to the social, cultural, and institutional dynamics of society. The integration between technological and social dimensions is a new direction in the development of a sustainable digital extension model.

This research departs from the need to understand how community-based digital counseling can strengthen local food security in regions vulnerable to climate uncertainty. The main objective of this study is to analyze the effectiveness of the use of digital platforms in improving farmers' adaptive abilities to climate change, as well as to identify the social factors that affect their success. This approach seeks to integrate quantitative analysis of changes in farmer behavior with a qualitative exploration of social experiences and dynamics at the community level. The selection of the research location in Parigi Moutong Regency, Central Sulawesi, is based on the characteristics of the area that is agrarian, has high vulnerability to climate change, and has great potential in the application of community digital technology. The area also has a strong social structure, allowing for the implementation of an effective participatory extension model. According to Syamsuddin (2023), this region shows an increasing trend of adoption of digital communication technology in the agricultural sector even though infrastructure is still limited. This makes Parigi Moutong an ideal context to test how the interaction between digital technology and community dynamics affects food security.

Theoretically, this research contributes to the development of a community-based agricultural extension model that is adaptive to climate uncertainty. The digital approach is considered to be able to expand the reach of communication, accelerate the dissemination of information, and strengthen the capacity of farmers to adapt to climate variability (Priya et al., 2025). This research also enriches the study of modern agribusiness by combining the perspectives of digital technology, rural sociology, and agricultural ecology. Thus, the results are expected to be the basis for the development of community-based digital extension theories in developing countries. Practically, this research is expected to provide relevant policy recommendations for decision-makers in the field of agricultural extension, especially in the context of digital transformation in rural areas. The results of the research can be used as a reference in designing a digital extension system that is inclusive, based on community participation, and responsive to climate change. By prioritizing collaboration between extension workers, farmers, and local institutions, this research seeks to create an intervention model that not only increases productivity, but also strengthens sustainable local food security in an era of climate uncertainty.

RESEARCH METHODS

Research Approach and Design

This study uses a mixed methods approach that combines quantitative and qualitative data sequentially to obtain a comprehensive picture of the effectiveness of community-based digital extension on local food security (Matović & Ovesni, 2023). This approach was chosen because it allows researchers to measure changes in farmers' behavior numerically while understanding their social experiences in adopting digital technology. The research design used is a sequential explanatory design, where the quantitative stage is carried out first to obtain statistical data, followed by the qualitative stage to explain the findings in depth (Toyon, 2021).

Population and Sampling Techniques

The population of this study is all farmer households in Parigi Moutong Regency, Central Sulawesi, who are involved in community-based agricultural activities and have access to digital extension programs. This district was chosen purposively because it has the characteristics of an active agrarian community, experiencing the impact of climate change, and is transitioning towards the application of agricultural digital technology. From this population, 80 farmer households were determined as quantitative respondents using the purposive sampling technique, with criteria namely active farmers, users of at least one extension digital application, and members of farmer groups. In addition, this study involved 5 key informants for the qualitative stage consisting of one agricultural extension worker, one community leader, one farmer group leader, and two farmers who are active users of digital platforms. The informant selection technique was carried out by snowball sampling to ensure that the participants involved had relevant experiences to the research context.

Data Collection Techniques and Instruments

Quantitative data was collected through a structured questionnaire compiled based on indicators of climate information access, adaptive agricultural practices, and household food security levels. Some of the questionnaire items were adapted from research instruments. The instrument was tested for validity through expert judgment by two academics in the field of agricultural extension and one field extension practitioner, while reliability was tested using Cronbach Alpha with a threshold of 0.70 as a reliability indicator. Qualitative data was obtained through participatory observation of digital counseling activities carried out by the community and in-depth interviews. The interview guide contains topics related to perceptions of the effectiveness of digital extension, implementation barriers, and changes in farmers' adaptive behavior. To strengthen the data triangulation, the researchers also collected secondary documents, such as reports on extension activities, rainfall data, and crop yield records during the three months of implementation.

Research Implementation Procedure

This research was carried out in four main stages. The first stage is preparation, which includes preliminary studies, coordination with the Parigi Moutong Regency Agriculture Office, and instrument trials. The second stage was quantitative data collection, where researchers distributed questionnaires to 80 farmer households with the help of local extension workers to ensure a high response rate. The third stage is qualitative data collection, carried out after the survey results have been temporarily analyzed, with the aim of exploring an in-depth explanation of statistical findings. The final stage is data synthesis and validation of results, which is integrating quantitative and qualitative findings to draw comprehensive conclusions.

Data Analysis Techniques

Quantitative data were analyzed using descriptive statistics to describe respondent profiles and changes in adaptive behavior, as well as paired t-tests to assess differences in

scores before and after the implementation of digital counseling. The analysis was carried out using the Statistical Package for the Social Sciences (SPSS) software version 26.0. Meanwhile, qualitative data was analyzed by thematic analysis methods, through steps: transcription, open coding, thematic grouping, and interpretation of results according to social context. The analysis was performed using the help of NVivo 12 Plus software to ensure traceability of findings and interpretive consistency. The integration of quantitative and qualitative results is carried out in the final stage through a comparative interpretation process, to gain a comprehensive understanding of how community-based digital extension affects local food security in situations of climate uncertainty.

RESEARCH RESULTS AND DISCUSSION

Increasing Access to Climate Information Through Digital Platforms

The results of a survey of 80 farmer households showed that the implementation of community-based digital counseling provided a significant increase in farmers' access to the latest climate and weather information. Before the program was implemented, most farmers (72.5%) only obtained climate information from field extension workers or based on personal experience. This condition causes delays in determining planting time and difficulty adjusting planting patterns to seasonal changes. After three months of implementing community digital platforms, the figure decreased to 18.7%, while 81.3% of farmers began to actively use farmer group instant messaging applications and online forums for digital extension as the main source of information. Test *t* Pairs showed significant differences between the level of access to information before and after the program ($T = 6.42$; $P < 0.001$), indicating that digital extension systems are effective in shortening the information gap between extension workers and farmers and accelerating the flow of communication within the community.

In addition to quantitative improvement, qualitative results also show that farmers have become more confident in making decisions related to agricultural activities because they feel they have an accurate and easily accessible source of information. One of the active user farmers said, *"In the past, we were just waiting for the extension workers to come and give news about the rainy season or planting, now we just have to look at the group, there is already information from many sources"* (F-02, interview August 12, 2025). The same thing was also conveyed by the chairman of the farmer group, *"With this digital platform, information circulates quickly and farmers can remind each other if there is an extreme weather change"* (K-01, interview August 10, 2025). This quote shows that digital innovation not only improves access to information, but also strengthens mutual trust and solidarity among members of farmer groups. This change in communication patterns shows that community-based digital technology is able to create a more participatory extension system. Farmers no longer play the role of passive recipients of information, but rather as part of a knowledge network that actively shares experiences and field data. This success also shows the great potential of the implementation of digital extension in agrarian areas such as Parigi Moutong, where communities have strong social closeness and a collective spirit in maintaining local food security amid climate uncertainty.

Table 1. Changes in Access to Climate Information Before and After the Implementation of Community Digital Platforms

Climate Information Resources	Before Program (%)	After the Program (%)	Change (%)
Field Extension Worker	45.0	12.5	-32.5
Personal/Traditional Experience	27.5	6.2	-21.3
Local Print and Radio Media	10.0	3.8	-6.2

Community Digital Platform (Farmer Group, Online Forum)	17.5	81.3	+63.8

Changes in Adaptive Agriculture Practices at the Community Level

Increasing access to climate information through digital platforms has a real impact on changing agricultural behaviors and practices at the community level. Based on the results of a survey of 80 farmer households, it was recorded that 65.0% of respondents began to adjust their planting patterns according to the digital weather forecast shared through community groups. In addition, 58.7% of farmers apply water conservation techniques such as *mulching*, the manufacture of infiltration wells, as well as the planting of drought-resistant varieties. A small percentage of farmers (23.8%) have also started using organic waste as a natural fertilizer to maintain soil moisture and reduce dependence on chemical fertilizers. Test results *t* Pairs showed significant changes in the rate of implementation of adaptive agricultural practices before and after program implementation ($t = 5.76$; $p < 0.001$). These findings show that increased access to information is followed by direct application in agricultural activities, not just increased knowledge. Farmers admitted that they were more confident in making decisions because they had access to guidelines that were easily accessible and in accordance with their local conditions. A field extension worker stated, *"In the past, farmers guessed a lot about when to plant, now they look at the rain forecast schedule in the group, then discuss themselves to determine the safest planting time."* (P-01, interview August 14, 2025). The same thing was conveyed by one of the farmers who use the digital platform, *"We can immediately share experiences, for example about how to save water or the right type of seeds. So don't wait for orders from extension workers anymore"* (F-01, August 11, 2025 interview). These two quotes illustrate that digital extension encourages farmer independence and collaboration through shared learning mechanisms at the community level.

Table 2. Changes in the Implementation of Adaptive Agriculture Practices Before and After Community Digital Programs

Types of Adaptive Practices	Before Program (%)	After the Program (%)	Change (%)
Adjustment of Planting Patterns Based on Digital Weather	25.0	65.0	+40.0
Application of Water Conservation (*mulching*, infiltration wells)	22.5	58.7	+36.2
Use of Dry-Resistant Varieties	18.7	52.5	+33.8
Utilization of Local Organic Fertilizers	12.5	36.3	+23.8

Increasing Household Food Security and Diversity Scores

Analysis of indicators *Household Dietary Diversity Score* (HDDS) shows a marked improvement in the aspects of household food security and diversity after the implementation of community-based digital counseling. The average HDDS score increased from 4.7 before the program to 6.2 after the program. Test *t* Pairs showed significant differences ($t = 5.89$; $p < 0.01$), indicating that active participation in digital extension had a positive impact on the diversification of food consumption of farmer families. The results of observations and interviews show that this increase occurs because farmers, especially women, are more active in participating in online discussions about household food management and the use of local

ingredients. The digital extension program also facilitates the exchange of recipes and food innovations based on local agricultural products, such as processing tubers and yard vegetables that were previously underutilized. One of the community leaders said, *"Now farmers often share cooking ideas from their own gardens, so they don't just depend on ingredients from the market."* (M-01, August 16, 2025 interview). Other farmers added, *"Through the digital group, we know the importance of growing vegetables in the yard for the family's daily needs"* (F-03, interview August 18, 2025). These two statements show that digital extension is not only focused on agricultural production, but also on strengthening family food security through inclusive community participation.

Table 3. Changes in Household Food Security and Diversity Score (HDDS)

HDDS Indicator (Score 0–12)	Before the Program	After the Program	Change	Value *t*	Significance (p)
Average HDDS Score	4.7	6.2	+1.5	5.89	< 0.01

Social and Institutional Dynamics in the Implementation of Digital Counseling

Qualitative findings show that the success of community-based digital counseling is determined not only by technological factors, but also by social dynamics and strong institutional support. Extension workers, community leaders, and farmer group administrators act as a liaison between technology and farmers, ensuring that the adoption process runs with a participatory approach. Although some farmers initially had difficulties in using digital devices, repeated training and mentoring systems helped to gradually improve their technological literacy. The process of communication in a digital group creates a new pattern of interaction that is more open and collaborative. Farmers can directly convey the problems faced in the field and receive responses from other members without having to wait for face-to-face meetings. This forms a pattern of collective learning that strengthens social solidarity and increases community confidence in the face of climate change. A farmer group leader revealed, *"In the past, information stopped at extension workers, now all members can participate in giving input and helping each other find solutions"* (K-01, interview August 15, 2025). While the extension worker added, *"Our role is now more as a companion, not an instructioner. Farmers have begun to independently manage information"* (P-01, interview August 14, 2025). These two quotes affirm that community-based digital counseling not only transforms the way of communication, but also strengthens local social and institutional capacity in maintaining food security amid climate uncertainty.

Discussion

The findings of the study show that community-based digital counseling is able to have a significant impact on improving local food security amid climate uncertainty. Increased access to climate information through digital platforms represents an important shift in the way farmers manage climate risks and make agricultural decisions. This condition supports the view that the digitalization of extension can serve as an adaptation instrument that accelerates the flow of knowledge and strengthens the capacity of farmers in dealing with environmental changes (Awad, 2021). When weather information and climate data are accessible in real-time through community online forums, farmers no longer rely on traditional experiences that are often inaccurate. This indicates that digitalization acts as a bridge between scientific knowledge and local practice, as expressed by Prajapati et al., (2025) that community-based digital collaboration accelerates the process of adopting innovations in adaptive farming systems

(Prajapati et al., 2025). Furthermore, the changes in adaptive behavior demonstrated through the implementation of water conservation, adjustment of planting patterns, and the use of drought-resistant varieties confirm that digital extension does not stop at increasing knowledge, but also drives the transformation of real practices. These findings are in line with the view Gryshova et al., (2024) which explains that the success of agricultural adaptation to the climate depends on the ability of farmers to integrate technological information into local decision-making (Gryshova et al., 2024). In the context of Parigi Moutong, this transformation shows that the presence of digital technology strengthens community agency, where farmers are not only recipients of information, but also producers of new knowledge through horizontal discussions among fellow farmers. This approach reinforces the idea that agricultural adaptation in the digital age is collaborative and participatory, not top-down as previous conventional extension models (Wijeratne & De Silva, 2024).

Another tangible impact can be seen in the increase in the Household Dietary Diversity Score (HDDS), which reflects the increase in household food security and diversity. These findings show that digital counseling has broader social implications, especially in empowering women farmers as important actors in household food management. This reinforces the argument Bocean (2024) that the success of digital agricultural innovation is not only measured in terms of productivity, but also in terms of its impact on food security and social welfare (Bocean, 2024). By facilitating online interaction between groups, digital platforms create spaces for women to share ideas, develop local food recipes, and manage household food resources more efficiently. Thus, community-based digital counseling acts as a catalyst for inclusive socio-economic development at the grassroots level. In addition to technical and social aspects, this research also reveals the importance of local institutional dynamics in supporting the success of digital counseling. The existence of extension workers, community leaders, and farmer group leaders as social facilitators plays a key role in maintaining the sustainability of the program. Qualitative results show that trust-based social relationships are the main foundation that allows digital technology to be accepted and used effectively. This view is in line with the findings Bonfanti et al., (2023), which affirms that community trust and solidarity are important factors in strengthening collective resilience to climate risks (Bonfanti et al., 2023). Thus, digital extension is not only a process of technology transfer, but also a form of social reconstruction that changes the power relations and roles between actors in the local agricultural system.

However, there are a number of challenges that need to be considered. Some farmers still face digital literacy barriers and limited network infrastructure in remote areas. Although training and mentoring are able to gradually improve technical capabilities, this gap shows the need for a more systematic digital capacity building strategy at the local level. These findings are consistent with the results of the study Yuan et al., (2025), which states that the digital literacy of extension workers and farmers is the main differentiating factor in the effectiveness of technology-based extension (Yuan et al., 2025). Therefore, future policies need to focus on building human resource capacity and expanding technological infrastructure in rural areas. Theoretically, this study expands the understanding of the concept of community-based digital extension as an innovative model in strengthening local food security. The integration between technological and social approaches provides a new framework in the study of adaptive agricultural extension in the era of climate change. The study also enriches the agribusiness literature and rural sociology by showing that food security is not only determined by production factors, but also by social networks, digital capacity, and community solidarity. Meanwhile, practically, this research provides an empirical basis for the development of agricultural extension policies that are more inclusive, collaborative, and based on local needs.

Although the results of the study showed positive achievements, it must be acknowledged that the limited implementation time of only three months is one of the weaknesses in measuring the long-term impact. In addition, the mixed methods approach used provides a comprehensive picture, but it can still be expanded through longitudinal studies to assess the sustainability of farmers' adaptive practices in the medium and long term. Further research is suggested to explore broader economic and ecological dimensions, such as production cost efficiency, changes in farmers' incomes, and impacts on the sustainability of natural resources. Thus, this study confirms that community-based digital extension in Parigi Moutong Regency has not only succeeded in increasing access to information and adaptive capacity of farmers, but also strengthens food security through sustainable social collaboration. These findings place digital transformation not just as a technological innovation, but as a relevant socio-ecological strategy in building resilient agriculture amid global climate uncertainty.

CONCLUSION

This study confirms that the implementation of community-based digital counseling is an effective strategy in strengthening local food security amid climate uncertainty. The results show that digital platforms can improve farmers' access to climate information quickly and relevantly, drive behavioural change towards more adaptive farming practices, and strengthen the collective capacity of communities to manage climate risks. This transformation not only increases farmers' knowledge and technical skills, but also strengthens social networks, solidarity, and trust between members of farmer groups. Thus, community-based digital extension has proven to be an efficient communication medium as well as a collaborative forum to accelerate the spread of sustainable agricultural innovations. Theoretically, this research makes an important contribution to the development of modern agricultural extension concepts that integrate digital technology and the values of social participation. Practically, the results of the research can be a reference for local governments, extension institutions, and community organizations in designing extension models that are more inclusive, adaptive, and in accordance with the local context. Going forward, strengthening rural digital infrastructure, increasing technology literacy for farmers, and sustainable mentoring are strategic steps to expand the positive impact of this model. By strengthening the role of communities as centers for adaptive learning, digital counseling can serve as a key pillar in building resilient and sustainable local food security in the era of climate change.

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