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The effectiveness of agricultural extension in rice farming in Bantaeng Regency, Indonesia: Employing structural equation modeling in search for the effective ways in educating farmers

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A R T I C L E I N F O

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A B S T R A C T

The research's objective was to examine the factors that directly and indirectly influence the effectiveness of agricultural extension in rice farming in Bantaeng Regency, Indonesia. The sample size included 155 rice farmers, and the Structural Equation Modeling (SEM) was used to examine the rice farmer data. The results indicated that latent variables such as farmer engagement (FER), family resources (FRR), application of product inputs (APR) ($\beta = 3.383$), and crop management (CMR, $\beta = -2.712$)) all have a significant effect on the effectiveness of agricultural extension (EAR). The findings of this study explained that the FER ($\beta = 0.244$), together with the FRR ($\beta = 0.923$), exerted a significant influence on the APR, potentially increasing rice production. Meanwhile, the APR ($\beta = 0.777$) provided good results on the CMR and EAR. The indirect effect hypothesis shows that the APR and CMR mediated the relationship between FER ($\beta = 0.203$), FRR ($\beta = 3.383$), and EAR, which emphasizes the importance of APR and CMR. Therefore, in improving the EAR programs, it is recommended that extension agencies and local governments provide support to rice farmers in their participation in agricultural organizations. This support should empower rice farming families, ensure proper allocation of agricultural inputs, and effectively manage rice crops using sustainable management principles. As a result of the findings of this study, individuals responsible for designing and managing agricultural extension programs will also gain important insights and data from the real world. Furthermore, as a consequence, agricultural extension agencies can continue to educate farmers and improve rice farming methods.

1. Introduction

The agricultural sector holds significant economic importance in numerous countries, particularly developing nations like Indonesia. In line with Salam et al. [1], agriculture is one of the sectors in the Indonesian economy that has consistently been emphasized and given central attention to the country's development goals. The significance of this sector in this country is in its contribution to enhancing the well-being of the Indonesian population [2]. It serves as the fundamental basis of the nation's economy [3]. The agriculture sector plays a significant role in Indonesia as it ranks as the third largest contributor to the Gross Domestic Product (GDP), catalyzing the nation's overall economic growth [3]. The agricultural, forestry, and fisheries industries contributed 12.40 percent to the Indonesian GDP in 2022, according to BPS data, 2023 [4]. In the context of the COVID-19 epidemic, the Indonesian economy contracted, but the agricultural sector grew

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positively [5,6]. During the previous three years, this sector has consistently demonstrated favorable expansion, with a growth rate of around 1.77 percent in 2020. During the previous three years, this industry has consistently demonstrated favorable expansion, with a growth rate of around 1.77 percent in 2020 [7,8], and the requirements of the food processing sector and other goods generated from rice.

The rice commodity has a significant contribution to national development in Indonesia. Large and stable rice production ensures food availability for most of the population and supports national food security. In addition, rice cultivation creates significant employment in rural areas, helps reduce poverty levels, and increases farmers' income [4]. However, rice farming in many developing countries is often faced with challenges of low productivity, lack of access to agricultural technology, and climate change [9–11]. This challenge is exacerbated by the low adoption of new and improved rice varieties, even though many new varieties have been developed, indicating a gap between technological innovations and agricultural practices on the ground [12]. Access to high-quality seeds is also a constraint for farmers in Indonesia. Qadir et al. [13] showed that although Indonesia has a formal seed system, there are still challenges in seed production and distribution, including weak linkages between seed stakeholders and inadequate resource management. This research focuses on the role of agricultural extension in providing information and how extension can facilitate farmers' access to high-quality seeds.

Therefore, efforts to increase rice production through various means need to continue, and one effective way is to increase the intensity of agricultural extension. Agricultural extension is crucial for enhancing rice production and farmers' quality of life. However, its effectiveness is frequently suboptimal [14]. Failure to provide relevant information, lack of farmer participation in extension programs, and resource constraints are some of the issues that need to be addressed to improve the effectiveness of agricultural extension [15–17]. Research by Kinarsih [12] also showed that although farmers have positive perceptions of extension services, there are gaps in the application of the information they receive into farming practices. In addition, factors such as age, education level, farming experience, and access to information can also affect farmers' capacity and capability to adopt innovations [18].

In increasing the productivity and sustainability of rice farming, agricultural extension has become a fundamental instrument [18–20]. Agricultural extension workers will assist farming communities in acquiring knowledge, skills, and new technologies through agricultural extension activities [21]. Furthermore, research conducted by Pello [22] in Kupang showed the role of extension workers in influencing rice technology innovation. Agricultural extension officers also play a role in the welfare of farmers in increasing income from agricultural products [23], and corroborated by research by Ristini [24] that agricultural extension officers play a real role in the yield of paddy rice products, especially as mentors and consultants.

The previous studies have identified various variables that contribute to agricultural extension effectiveness [19,25–28]. Nevertheless, a scarcity of research has been employed to comprehensively examine the interplay and impact of these variables directly and indirectly on the effectiveness of agricultural extension in rice cultivation. Hence, the primary objective of this research was to examine the factors that directly and indirectly influence the effectiveness of agricultural extension in rice farming in Bantaeng Regency. As a result of the research objectives being met, it was anticipated that the findings would lead to a better knowledge of the factors that need to be taken into consideration when educating farmers and developing and carrying out agricultural extension activities that are more effective. As a consequence of this, it is possible that this will contribute to increased output and sustainability in the cultivation of rice.

2. Literature review and conceptual framework

2.1. The effect of farmer engagement in agricultural extension

Farmer involvement in agricultural extension programs significantly impacts agricultural technology acceptance, farm performance, farmer empowerment, and agricultural sustainability development. Research by Spielman & Pandya-lorch [29]; Xu et al. [30] shows that farmers who are more involved in extension programs are more likely to accept new agricultural technologies. Farmers' involvement in the planning and implementation stages of extension programs increases their understanding of the benefits of new technologies, thereby increasing the likelihood of acceptance and adoption. Then, Anwarudin & Dayat [26] found that farmers' involvement in extension positively impacts agricultural performance. Farmers involved in extension programs tend to have better and more sustainable results. In line with the results of the previous studies, Arbain et al. [31] revealed that farmer involvement in extension can be a means to empower farmers. The involvement of farmers in the decision-making and planning process will encourage farmers to feel they have control over their businesses and are better able to overcome agricultural challenges. In addition, Qiao et al. [32] highlighted the importance of farmer involvement in developing sustainable agricultural practices. Farmers who are involved in extension programs tend to be more concerned about environmental issues and more willing to implement sustainable agricultural practices.

Farmers' participation in agricultural extension programs is essential in achieving agricultural success and sustainability. Researchers in Northern Ghana found that participation in ACDEP agricultural extension programs did not significantly increase crop yield. However, it significantly increased farm income, emphasizing the need for connecting farmers, markets, and agricultural technologies [28]. Internal and extrinsic incentives influence the involvement of farmers in extension programs in Nepal. It has been recognized that providing high-quality extension services is crucial in promoting technology adoption and enhancing agricultural production [33].

In addition, several other studies have highlighted different aspects of farmer participation in agricultural extension. Rivera & Qamar [34] emphasized the important role of agricultural extension in rural development and food security. Anderson & Feder [35] discussed challenges and realities in agricultural extension implementation, while Davis et al. [36] evaluated the positive impact of farmer field schools on productivity and poverty alleviation. Birner & Anderson [37] and Feder et al. [38] provided insights on making agricultural extension more demand-driven and its impact on adopting integrated pest management practices. This research emphasizes the importance of effective farmer engagement in agricultural extension programs to achieve sustainable agricultural development and food security. Within this framework, farmer participation should be a key focus in the planning and implementing of effective agricultural extension programs.

2.2. The effect of family resources on agricultural extension

There is no debate about the importance of agricultural extension in increasing farmers' productivity and welfare. Family resources play an important role in affecting the success and outcomes of extension activities, which is sometimes underestimated. This statement follows research by Sevedi et al. [33] that one of the factors affecting farmers' participation in agricultural extension is family resources (household size), as it relates to the division of tasks in the household. Consequently, farmers with many family resources will help implement extension programs. This finding is also supported by Khalid and Sherzad [39], who state that extension activities aim to improve the efficiency of farming families, increase production, and generally improve the living standards of farming families. In addition, gender roles in access to and control over family resources are also related to agricultural extension. Research by Mugonola et al. [40] and Quisumbing & Pandolfelli [41] explain that gender inequality can influence family resource management decisions and their impact on the effectiveness of agricultural extension. It indicates that family resources significantly impact the effectiveness of agricultural extension because they form the foundation of farmers' abilities to participate in and accept new technology in agricultural practices. According to research conducted in China, farmers' adoption of new technology increased their operating revenue, highlighting the importance of family resources in embracing agricultural innovations. Education, farming experience, and access to fresh information have all been found to impact technology adoption decisions, affecting farmers' operating revenue [42].

Human capital theory and the Resource-Based View (RBV) can enrich the understanding of how family resources affect the success of rice farming extension. Human capital theory by Becker [43] emphasizes that family members' education, skills, and farming experience determine their ability to absorb and adopt new technologies from extension. Meanwhile, RBV highlights that the family's internal resources, such as labor, access to capital, and information, are important assets that assist farming families in utilizing knowledge gained from extension [44]. Thus, families with more resources tend to implement agricultural innovations successfully, which were introduced through extension [45]. Therefore, it is imperative to prioritize endeavors to guarantee farmers' adequate access to familial resources, as this constitutes a crucial measure in enhancing the efficacy of agricultural extension services and attaining the objectives of sustainable agriculture and food security objectives.

2.3. Effect of application product inputs on agricultural extension

Farmers who receive extension services on the correct and timely application of these inputs will likely achieve better yields. This statement is consistent with research by Giller et al. [46], which showed that proper and efficient use of production inputs, such as organic and chemical fertilizers, in the context of agricultural extension can significantly increase agricultural productivity. Furthermore, proper application of production inputs can reduce the risk of agricultural yield losses. Kahan [47] revealed that a better understanding of production input application in extension can help farmers reduce the risk of crop losses. One of the extension studies commonly given to farmers is the use of pesticides. Li et al. [48] explained in their study that excessive pesticide use increases the risk of neurological dysfunction among farmers, with somatosensory tiny fibers most likely to be affected. In addition, the effect of application product inputs in extension is the improvement of agricultural sustainability. Then, according to research by Mustapit et al. [49], an extension that includes the application of sustainable product inputs, such as organic fertilizers and environmentally friendly farming techniques, can help improve agricultural sustainability. This condition involves the use of more efficient and environmentally friendly inputs. Allahyari [50] research also found that current agricultural extension must consider environmental implications, social issues, and overall economic growth in the agricultural sector. Moreover, a study submitted by Iskandar et al. [38] highlighted the importance of extension in empowering farmers to use product inputs. Appropriate extension can help farmers make better decisions in terms of input use, which in turn increases their control and income. The effect of product input application in extension is an essential factor in the success of agricultural extension programs. Appropriate and efficient use of production inputs can increase productivity, reduce the risk of agricultural losses, improve agricultural sustainability, and empower farmers.

These studies emphasize the importance of incorporating product input application training into agricultural extension programs. The extension can help farmers increase productivity, reduce the risk of losses, and implement sustainable farming practices by providing relevant information and training. Feder et al. [51] and Spielman et al. [52] highlight how agricultural extension can encourage the adoption of better practices, such as integrated pest management and other agricultural innovations. Knowler & Bradshaw [53] add that extension can also encourage farmers to shift to more sustainable conservation agriculture practices. Overall, these references reinforce the idea that effective agricultural extension, which includes training on the application of product inputs, is critical to the success and sustainability of agriculture. Training on the application of product inputs, is critical to the success and sustainability of agriculture.

2.4. Effect of crop management on agricultural extension

Agricultural extension plays a vital role in improving farmers' productivity and welfare. Crop management, including variety selection, fertilizer use, pest control, and other cultivation techniques, is essential to agricultural production. Verma [54] research showed that extension focusing on crop management can significantly improve the productivity and quality of agricultural produce. Knowledge provided to farmers on proper cultivation techniques, selection of suitable varieties, and fertilizer management can positively impact crop yields. In their study, Argaw et al. [55] provided empirical evidence supporting the notion that agricultural extension plays a crucial and constructive role in enhancing agricultural productivity. This statement is achieved by enhancing farmers' understanding of agronomic practices, including pest and disease management, and adopting improved seed varieties and soil and water conservation technologies. Like production inputs, agricultural extension also influences crop management, especially in minimizing agricultural losses. According to research by Akhtar et al. [56] and Kahan [47], an extension that includes agricultural risk management can help farmers reduce the risk of losses due to natural disasters or other factors. A good crop-management strategy can protect against price fluctuations and uncertain weather conditions. Then, Sjah et al. [57] highlighted that good crop management can empower farmers. Through extension, farmers can make better decisions about their crop management and feel more in control of their farming business. The study conducted by Anang [58] demonstrated that institutional factors, such as the availability of agricultural extension consultation services and subsidized fertilizers, had a crucial role in promoting the adoption of enhanced varieties.

Furthermore, research by Feder et al. [38], Knowler & Bradshaw [53], and Davis et al. [59] highlight the positive impact of farmer field schools and similar extension programs in increasing agricultural productivity, reducing poverty, and encouraging the adoption of sustainable practices such as conservation agriculture and integrated pest management [60]. Benin et al. [61] emphasize the importance of policies supporting sustainable land management, which can be enhanced through effective agricultural extension. Overall, these studies confirm the important role of agricultural extension in disseminating good crop management knowledge and practices, contributing to increased yields, sustainability, and farmer welfare.

2.5. Conceptual framework

This study used two exogenous latent variables, farmer engagement, and family resources, and then three endogenous latent variables: application product inputs, crop management, and agricultural extension effectiveness. Fig. 1 presents the conceptual framework model of this study, in which it was assumed that the Application of Product Inputs and Crop Management as mediating variables had a direct effect on Agricultural Extension Effectiveness. Farmer Engagement and Family Resources were each suspected to affect Agricultural Extension Effectiveness indirectly.

This conceptual framework, in Fig. 1, illustrates the complex relationship between various factors contributing to agricultural extension's effectiveness. Overall, the framework aligns with the Diffusion of Innovations Theory, which explains how innovations, such as new agricultural technologies and practices, spread and are adopted by individuals within a social system. In this context, agricultural extension

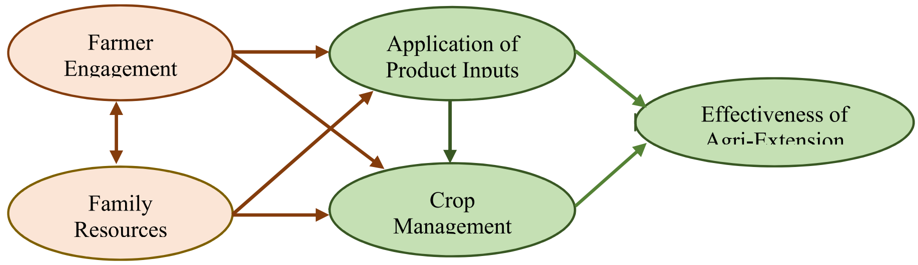

Fig. 1. Conceptual framework model on the effectiveness of agricultural extension research in rice farming.

is the main channel for disseminating such innovations to farmers.

More specifically, the framework highlights the important role of human and social capital in the innovation adoption process. Farmer engagement reflects aspects of social capital, where interactions and social networks between farmers and agricultural extension facilitate knowledge exchange and increase trust, promoting innovation adoption. Family resources, including education level, farming experience, and access to information, represent human capital that influences farmers' ability to understand and implement innovations. In addition, proper crop management and input product application, often the focus of extension programs, are key factors in improving agricultural productivity and sustainability. Previous studies, such as those by Feder et al. [38] and Davis et al. [59] on the impact of farmer field schools, as well as studies on agricultural technology adoption [54,60], provide empirical evidence supporting the relationships described in this framework.

3. Research methods

3.1. Location and time of research

This study was conducted in Bissappu District, Bantaeng Regency, South Sulawesi Province, Indonesia (Fig. 2). The selection of the research location was made purposively with the consideration that Bantaeng Regency is one of the rice-producing areas in South Sulawesi and most of the population depends on the agricultural sector for their livelihoods. This situation creates an ideal environment for understanding how rice farming extension can impact agricultural sustainability and farmer welfare. This research was conducted in January 2023.

3.2. Data collection sources and methods

The type of data used in this study was quantitative data. Quantitative data is data in numbers collected through survey methods or other research techniques [62]. However, Table 2 presents the transformation of some of the quantitative-continuous data collected into nominal or categorical data. This transformation is represented in columns (4), (5), and (6) of the table. The transformation of the data is a treatment that we carried out to adjust to the compatibility of the AMOS program. This study involved direct interviews with rice farmers in Bantaeng Regency, utilizing a pre-prepared questionnaire as the survey instrument. This study utilized primary data as its source of information. We collected primary data through structured interviews with rice farmers, utilizing a pre-formulated questionnaire [63].

3.3. Population and sample

The population of this study were rice farmers in Bissappu District, Bantaeng Regency. The researchers employed a simple random sampling technique to select participants for the study. The participants in this study were rice farmers who met the following criteria: a) they planted rice during the final planting season of the year 2022; b) the rice growth during the season was normal; and c) there were no instances of flooding or drought during the growing period. The sample selection method in this study was simple random sampling. This method involved randomly picking individuals from the population of rice farmers who met the above criteria without accounting for any strata that may exist within the population [64]. Then, from this population, we determined the required sample size by applying the Cochran formula [65,66] as follows:

$$n = \frac{Z^2 pq}{e^2}$$

Where n is the number of samples required, Z is the price of the normal curve for a 95 % deviation = 1.64, p and q are the 50 % chance of being right and 50 % chance of being wrong, respectively, and e is the sampling error rate, which is 10 %. Then, the number of samples obtained for this study is as follows:

$$n = \frac{Z^2 pq}{e^2} = \frac{(1,96)^2 (0,5)(0,5)}{(0,10)^2}$$

$$n = 96,04$$

The sample calculation using the Cochran formula shows that the

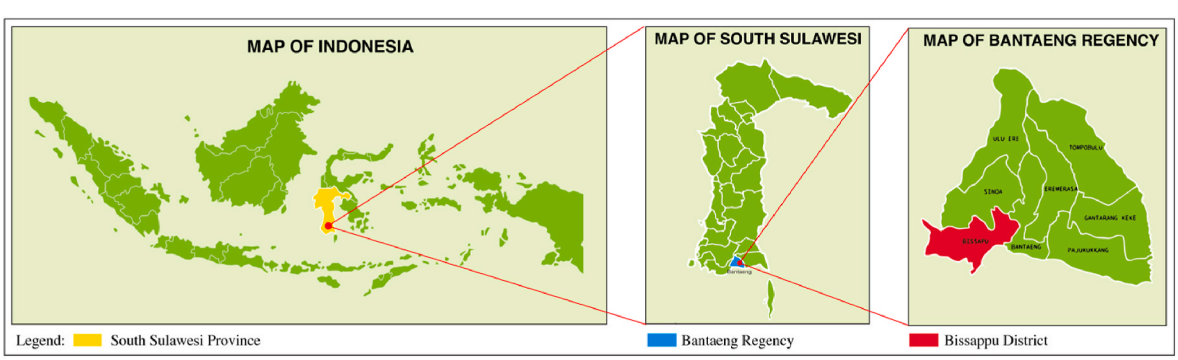

Fig. 2. Map of the research locations.

Table 1
Measurement and structural equations on the path diagram.

a. Measurement Equation Model

Endogenous latent variables	Exogenous latent variables
Application of Product Inputs (η1)	Farmer Engagement (ξ1)
APR1 = $\lambda_7\eta1 + \varepsilon1$	FER1 = $\lambda_1\xi1 + \delta_1$
APR1 = $\lambda_8\eta1 + \varepsilon2$	FER2 = $\lambda_2\xi1 + \delta_2$
APR1 = $\lambda_9\eta1 + \varepsilon3$	FER3z = $\lambda_3\xi1 + \delta_3$
APR1 = $\lambda_{10}\eta1 + \varepsilon4$	Family Resources (ξ2)
Crop Management (η2)	FRR1 = $\lambda_4\xi2 + \delta_4$
CMR1 = $\lambda_{11}\eta2 + \varepsilon5$	FRR2 = $\lambda_5\xi2 + \delta_5$
CMR2 = $\lambda_{12}\eta2 + \varepsilon6$	FRR3 = $\lambda_6\xi2 + \delta_6$
CMR3 = $\lambda_{13}\eta2 + \varepsilon7$	
CMR4 = $\lambda_{14}\eta2 + \varepsilon8$	
Effectiveness of Agricultural Extension in Rice Farming (η3)	
EAR1 = $\lambda_{15}\eta3 + \varepsilon9$	
EAR2 = $\lambda_{16}\eta3 + \varepsilon10$	
EAR3 = $\lambda_{17}\eta3 + \varepsilon11$	
EAR4 = $\lambda_{18}\eta3 + \varepsilon12$	
EAR5 = $\lambda_{19}\eta3 + \varepsilon13$	

where is:

ξ (ksi)	: Exogenous latent variable
η (eta)	: Endogenous latent variable
γ (gamma)	: Parameters of direct relationship between exogenous variables and endogenous variables
β (beta)	: Parameters of direct relationship between endogenous variables and other endogenous variables
ζ (zeta)	: Structural error in the endogenous variable
δ (delta)	: Measurement error associated with exogenous variables
ε (epsilon)	: *Measurement error* associated with endogenous variables
λ (lambda)	: Factor loadings, direct relationship parameters between latent variables and their indicators

b. Structural Equation Model
$\eta1 = \gamma1\xi1 + \gamma4\xi2 + \zeta1$
$\eta2 = \gamma3\xi1 + \gamma2\xi2 + \beta1\eta1 + \zeta2$
$\eta3 = \beta2\eta1 + \beta3\eta2 + \zeta3$

number of samples in this study is at least 96 respondents. In this study, we selected 155 rice farmers in Bissappu District, Bantaeng Regency, as respondents and the study sample. Prior to completing the interview, consent was secured from each respondent. The research obtained authorization from the local administration of Bantaeng Regency and the South Sulawesi Province Governor's Research Licensing Division Committee (Dinas Penanaman Modal dan Pelayanan Terpadu Satu Pintu) on January 2, 2023, through Permit Letter No. 69/S.01/PTSP/2023.

3.4. Data analysis method

3.4.1. Structural equation modeling analysis (SEM)

Structural Equation Modeling (SEM) is a statistical technique that examines both interdependent and dependent multivariate data, specifically confirmatory component analysis and route analysis. The variables being examined are latent variables, often known as constructs. These characteristics are not readily observable, but are analyzed using measurable indicators known as manifest variables. The primary objective of SEM is not to generate models but to evaluate and validate theory-based models, specifically measurement and structural models [67]. SEM analysis begins with observations and literature studies based on relevant theories to serve as a reference in creating a conceptual framework. Furthermore, the operational definition of variables will be formulated, and a measurement model will be obtained. Next, the structural and measurement models are integrated to obtain a hybrid model. This hybrid model will be confirmed with data through the SEM application. In this study, the model specifications developed were presented in Fig. 3. The measurement and structural equations of the variables used on the path diagram in Fig. 3 are presented in Table 1. Furthermore, to facilitate the readers, the description of the variables and the measurement units of the research are presented in Table 2.

3.4.2. Research process steps

The data analysis process using Structural Equation Modeling (SEM) is a complex yet powerful statistical method for understanding the relationships between variables in a model. Here are the main steps in SEM analysis (Fig. 4).

1. Data Preparation

At this stage, the data for SEM analysis must be carefully prepared. Data must be obtained from valid and accurate sources. The research data collected through the questionnaire instrument is inputted into the data analysis application to test the validity and reliability of the instrument. If it meets the criteria, it will be analyzed in the SEM testing application.

2. Evaluation of the Measurement Model

In SEM analysis, evaluating the measurement model used to measure the constructs is important. This measurement model maps observed variables (indicators) into latent variables (constructs). The measurement model is analyzed by calculating construct reliability, convergent validity, and discriminant validity. If the calculation results meet the criteria, then analyze the goodness of fit (GoF) on the model specifications of both the measurement and structural models. However, if it does not meet the criteria, it is necessary to improve the model specifications.

3. Goodness of Fit Model

The proposed structural model is evaluated based on how well it fits the facts. The structural model specification defines the relationship between the latent variables and the suggested research hypotheses. The results of the model fit study reveal that the model matches the data well. This model explains the relationship between variables well and supports the research hypothesis. The SEM analysis includes various test indices, including CMIN/DF, RMSEA, TLI, CFI, NFI, and PNFI, as outlined in the study techniques. In the evaluation standards employing CMIN/DF, a latent variable is considered acceptable (feasible) if its value is below 2.00. If the RMSEA value is below 0.08, the latent variable is considered viable according to the requirements. A TLI, CFI, and NFI value is considered practical if it exceeds 0.90. If the PNFI index yields a higher value, it indicates a stronger fit of the model. After the goodness of fit test has met the criteria, the next step is to conduct a significance analysis to answer the hypothesis that was designed at the beginning. However, if the goodness of fit criteria is not met, it is necessary to take steps to modify the index by following several recommendations provided by the SEM analysis application.

Table 2
The description of the variables and the measurement units of the research.

Latent and Indicator Variable Names			Measurement Units[a]		
Latent Variable Names	Indicator Variables (IV) [References]	Symbols of IV	Type of Baseline Data (BD) (Original Primary Data)	Converted BD into Binary/Ordinal Data	Inputted Data in AMOS Sofware
(1)	(2)	(3)	(4)	(5)	(6)
Farmer's Engagement in an Agricultural Organization (FER)	Become a member of a farmer group [21,24]	FER1	Categorical data	Binary data	[1 = yes], [0 = no]
	Actively participate in farmer groups [25,26]	FER2	Likert scale	5PLS	[1 = never], [2 = seldom], [3 = sometimes], [4 = often], [5 = always]
	Frequency of extension activities participated in 2022 [27]	FER3	time(s)	time(s)	[frequency participating in extention activies]
Family Resources (FRR)	Farmer farming experience [28,29]	FRR1	Likert scale	3PLS	[1 = less than 23 years old], [2 = 23 years–33 years old], [3 = over 33 years old]
	Farmer age [30]	FRR2	Likert scale	3PLS	[1 = less than 41 years old], [2 = 41 years–58 years], [3 = over 58 years old]
	Farmer occupation type [31]	FRR6	Categorical data	Binary	[0 = only farmers], [1 = farmer plus a side job]
Application of Product Inputs (APR)	Seed application [33]	APR1	kg	3PLS	[1 = less than 27.00 kg], [2 = 27.00 kg–38.00 kg], [3 = more than 38.00 kg]
	Pesticide application [33, 34],	APR2	ha	3PLS	[1 = less than 0,8 L], [2 = 0,8L to 1,20 L], [3 = more than 1,20 L]
	Application of urea fertilizer [35,36]	APR3	kg/ha	3PLS	[1 = less than 241.00 kg], [2 = 241.00 kg–338.00 kg], [3 = more than 338.00 kg]
	Application of phonska/ NPK fertilizer [49]	APR4	kg/ha	3PLS	[1 = less than 149.00 kg], [2 = 149.00 kg–209.00 kg], [3 = more than 209.00 kg]
Crop Management (CMR)	*Legowo* planting system application[b] [38]	CMR1	Categorical data	Binary data	[1 = yes]; [0 = no]
	Seed source used [39]	CMR2	Categorical data	Ordinal data	[0 = own production], [1 = buying], [2 = subsidies]
	Rice paddy seed varieties used [40,41]	CMR3	Categorical data	Binary data	[1 = certified], [0 = local/other]
	Types of crops cultivated [42]	CMR4	Categorical data	Ordinal data	[0 = rice only], [1 = rice and other food crops], [2 = rice and annual crops], [3 = rice, other food crops, and annual crops]
Effectiveness of Agricultural Extension in Rice farming (EAR)	Labour Productivity [16]	EAR1	man-days/ha	3PLS	[1 = low], [2 = medium], [3 = high]
	Land Productivity [20]	EAR2	kg/ha	3PLS	[1 = less than 3350.00 kg], [2 = 3350.00 kg to 4690.00 kg], [3 = more than 4690.00 kg]
	Capital Productivity [21]	EAR3	IDR/ha	3PLS	[1 = less than IDR 4,009,166], [2 = IDR 4,009,166 to IDR 5,613,217], [3 = more than IDR5,613,217]
	Revenue [22]	EAR4	IDR/ha	3PLS	[1 = less than IDR 11,405,711], [2 = IDR 11,405,711.00 to IDR15,969,091.00], [3 = more than IDR 15,969,091.00]
	Gross Margin [23]	EAR5	IDR/ha	3PLS	[1 = less than IDR 15,342,327.00], [2 = IDR 15,342,327.00 to IDR21,480,730.00], [3 = IDR 21,480,730.00]

[a] Note: PLS (Point of Likert Scale); IDR=Indonesian Rupiah (Indonesian Currency).
[b] *Legowo* planting system is a technological innovation in rice planting in Indonesia.

4. Interpretation of results and conclusions

The last phase of the study design includes testing model hypotheses, interpreting findings, and formulating conclusions and recommendations. Once the SEM requirements are met, this phase begins. The model must be rectified and restarted if it fails to meet all conditions. The initial phase of SEM effect analysis involves the examination of both direct and indirect effects. The direct effect is determined by the construct reliability (CR) number obtained by AMOS Software, which is greater than 1.96 or has a p-value less than 0.05. The indirect effect can be determined using the Sobel Test, which involves comparing the z-statistic to the critical z-value (1.96) or the p-value to a significance level of 0.05.

5. Results

5.1. Evaluation of the measurement model

This research model consists of 5 (five) latent variables, including the variables of Farmers Engagement in an Agricultural Organization (FER), Family Resources (FRR), Application of Production Inputs (APR), Crop Management (CMR), and Effectiveness of Agricultural Extension in Rice Farming (EAR). In determining whether or not a latent variable is reliable and consistent, one of the most important tasks is to determine how each latent variable is connected to the others to measure the model. The following processes are performed in order to accomplish this.

5.1.1. Convergent validity testing

The purpose of latent validity testing is to ascertain the validity of the indicator variables employed in measuring latent variables. The loading factor value (standardized regression weights) can be used to assess the validity of each indicator in measuring latent variables. If the loading factor value is > 0.5, convergent validity properties will be achieved based on a good loading factor size. The results of validity testing are presented in Fig. 5 and Table 3. According to the data presented in Tables 3 and it is evident that the loading factor values for the FER, FRR, APR, CMR, and EAR variables exceed 0.5. These values suggest that these indicators possess validity in assessing latent variables.

5.1.2. Latent variable reliability testing

The reliability of latent variables is measured by three criteria, namely construct reliability (CR), Cronbach's Alpha (CA), and Average Variance Extracted (AVE) from indicators that measure latent variables.

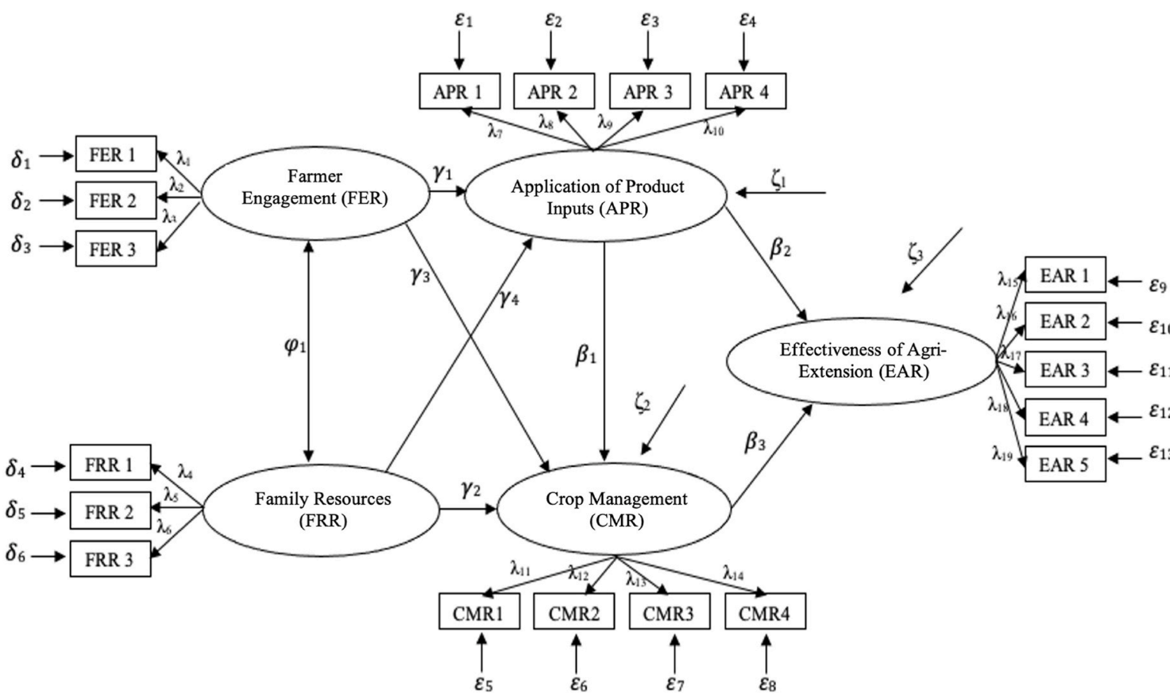

Fig. 3. The hybrid model of the effectiveness of agricultural extension in rice farming.

Latent variables are reliable if the CR or CA value is above 0.7 and or the AVE value is greater than 0.5. The results of measuring the reliability of latent variables can be seen in Table 4.

Based on Table 4, the criterion test measures the latent variable reliability test, namely CR and CA, from the indicators that measure the latent variable. Latent variables are declared reliable if the value is above 0.7. In addition, there is an AVE for the five latent variables greater than 0.5, so it can be concluded that the construct is reliable.

5.2. SEM model fit test

The objective of model feasibility testing is to evaluate the appropriateness (feasibility) of the latent variables that have been constructed. Table 5 summarizes the outcomes obtained from the model feasibility testing conducted in this study.

Table 5 reveals that the six indices, namely probability (p-value), CMIN/DF, RMSEA, TLI, CFI, and NFI, do not match the criterion for the goodness of fit. However, the PNFI value does meet the criteria. Based on the goodness of fit analysis findings, it can be inferred that the structural equation modeling (SEM) path diagram constructed in this study is not viable. Hence, the index covariance model is modified to achieve a well-suited model. The structural equation modeling (SEM) model utilized in the AMOS program is a covariance-based SEM (CB-SEM) model designed to incorporate the covariance component. Fig. 6 displays the path diagram after the adjustment of the covariance index. The outcomes of evaluating the adequacy of the model's fit following the adjustment of the covariance index are presented in Table 6.

Table 6 demonstrates that the goodness of fit for the seven indices, namely p-value, CMIN/DF, RMSEA, TLI, CFI, NFI, and PNFI, has met the criterion after adjusting the covariance index. Based on these findings, it can be inferred that the SEM path diagram developed in this study is deemed appropriate and can be utilized.

5.3. R-square test

The R-square test in structural equation modeling (SEM) analysis is employed to assess the extent to which exogenous variables contribute to endogenous variables and the model's capacity to account for endogenous fluctuations. In the AMOS application, the R-square value can be seen in the square multiple correlations table. Table 7 presents the results of the R-square estimate.

According to the data presented in Table 7, the R-square value for the Application of Production Inputs (APR) is 0.863. This figure indicates that the exogenous variables, namely Farmers Engagement in an Organization (FER) and Family Resources (FRR), collectively account for 86.3 % of the variance in the Application of Production Inputs (APR) variable. Furthermore, the remaining 13.7 % of the variance can be attributed to additional variables not incorporated into the research model. The R-square value for Crop Management (CMR) was found to be 0.989. The data indicates that the exogenous variables, specifically Farmers Engagement in an Organization (FER), Family Resources (FRR), and Application of Production Inputs (APR), collectively account for 98.9 % of the variation in the Crop Management (CMR) variable. The remaining 1.1 % is attributed to other factors not considered in this research model.

Moreover, the efficacy of Agricultural Extension in Rice Farming (EAR) is demonstrated by an R-square coefficient of determination of 0.924. This figure illustrates that the exogenous variables, specifically Farmers Engagement in an Organization (FER), Family Resources (FRR), Application of Production Inputs (APR), and Crop Management (CMR), collectively account for 92.4 % of the variation in the Effectiveness of Agricultural Extension in Rice Farming (EAR) variable. The remaining 7.6 % is attributed to other factors not considered in this research model.

Based on Table 8, it can be concluded that the relationship between exogenous variables and endogenous variables is included in the criteria for a very strong relationship for the three endogenous variables, namely Application of Production Inputs (APR), Crop Management (CMR), and Effectiveness of Agricultural Extension in Rice Farming (EAR).

5.4. Hypothesis testing: direct and indirect effects

Hypothesis testing involves assessing the statistical significance of the association between latent variables and deciding whether to accept or reject the hypothesis. Hypothesis testing is considered acceptable at this step if the t-statistic value exceeds the t-table, the critical ratio is greater than 1.96, and the p-value is less than 0.05 or a significance level

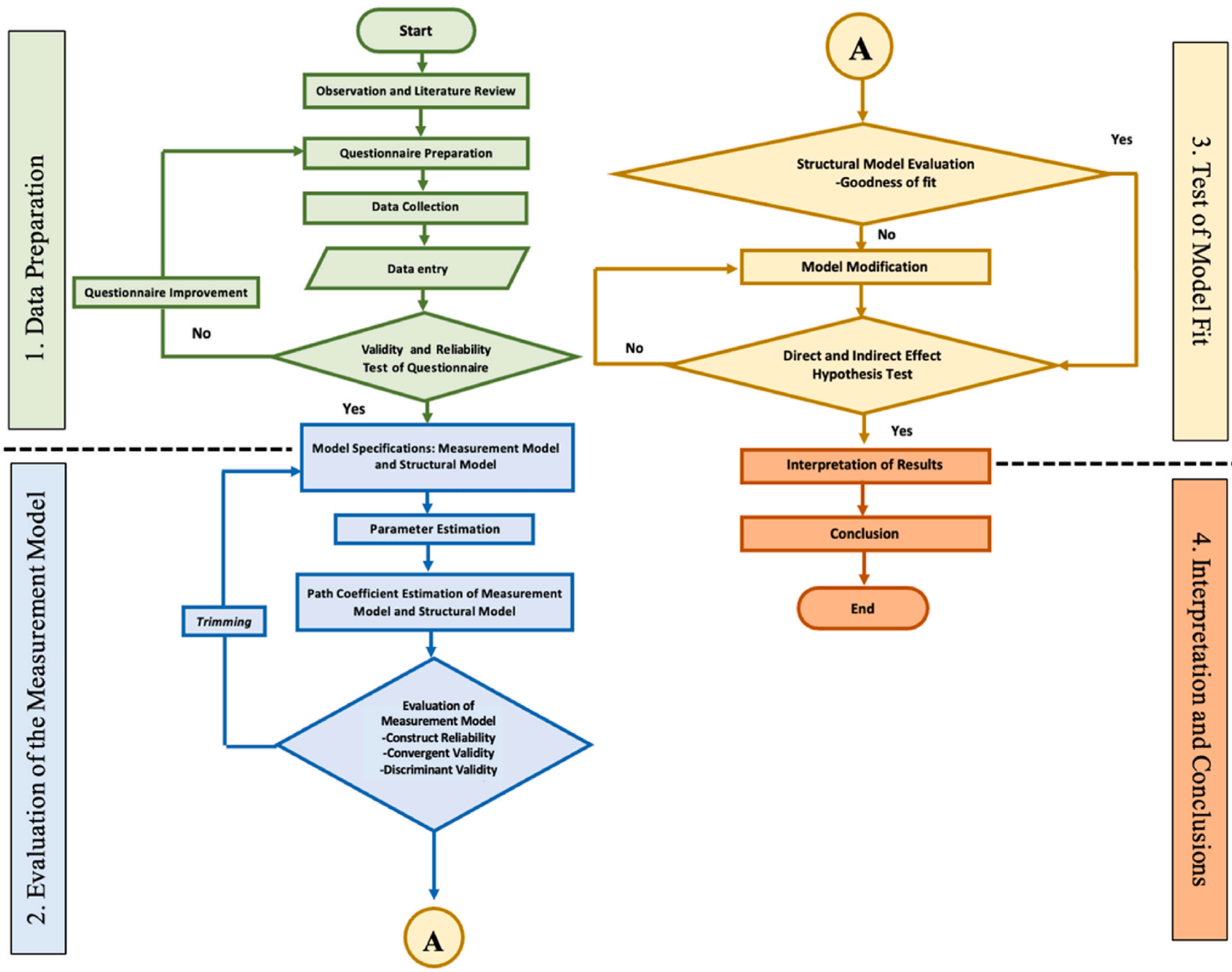

Fig. 4. Flowchart of the research.

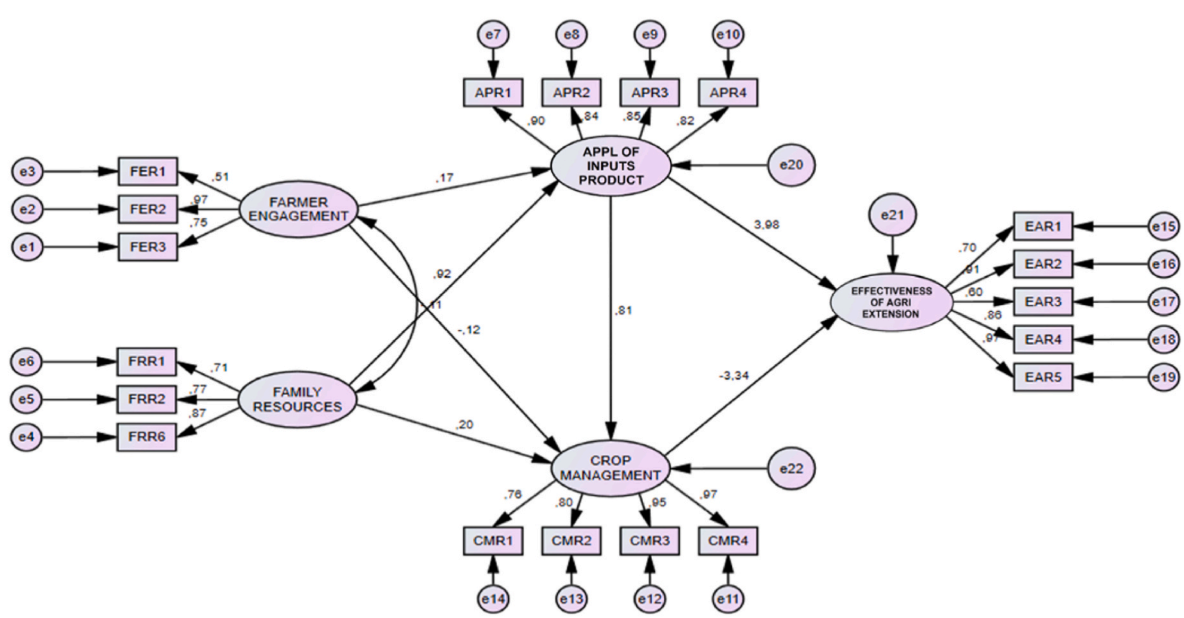

Fig. 5. Path diagram of construct validity test.

Table 3
Construct validity test.

Latent Variables	Indicators	Loading Factors	Criteria	Descriptions
Farmer Engagement in an Agricultural Organization (FER)	FER1	0.507	0.5	Valid
	FER2	0.974	0.5	Valid
	FER3	0.749	0.5	Valid
Family Resources (FRR)	FRR1	0.710	0.5	Valid
	FRR2	0.767	0.5	Valid
	FRR6	0.873	0.5	Valid
Application of Product Inputs (APR)	APR1	0.900	0.5	Valid
	APR2	0.840	0.5	Valid
	APR3	0.848	0.5	Valid
	APR4	0.818	0.5	Valid
Crop Management (CMR)	CMR1	0.761	0.5	Valid
	CMR2	0.798	0.5	Valid
	CMR3	0.951	0.5	Valid
	CMR4	0.968	0.5	Valid
Effectiveness of Agricultural Extension in Rice Farming (EAR)	EAR1	0.699	0.5	Valid
	EAR2	0.911	0.5	Valid
	EAR3	0.602	0.5	Valid
	EAR4	0.858	0.5	Valid
	EAR5	0.973	0.5	Valid

Table 4
Latent variable reliability test.

Latent Variables	*Construct Reliability*	*Cronbach's Alpha*	AVE	Description
Farmer Engagement in an Agricultural Organization (FER)	0.801	0.746	0.589	Reliable
Family Resources (FRR)	0.828	0.792	0.618	Reliable
Application of Product Inputs (APR)	0.913	0.916	0.725	Reliable
Crop Management (CMR)	0.927	0.913	0.764	Reliable
Effectiveness of Agricultural Extension in Rice Farming (EAR)	0.909	0.901	0.672	Reliable

Table 5
The goodness of fit model.

Index	*Goodness of Fit*	*Cut Off Value*	Description
P-value	0.000	≥0.05	*Poor of Fit*
CMIN/DF	4.503	≤2.00	*Poor of Fit*
RMSEA	0.151	≤0.08	*Poor of Fit*
TLI	0.806	≥0.90	*Poor of Fit*
CFI	0.836	≥0.90	*Poor of Fit*
NFI	0.801	≥0.90	*Poor of Fit*
PNFI	0.674	the bigger the fit	*Good of Fit*

of 5 % [68]. The direct and indirect effects test analysis results can be seen through the summary in Tables 9 and 10, respectively.

Table 9 suggests that the variable Farmers Engagement in an Agricultural Organization (FER) positively and significantly impacts the Application of Production Inputs (APR). The test findings indicate a coefficient value of 0.244, which is positive. The t-statistic of 4.405 also suggests that the value exceeds 1.96, indicating statistical significance. The p-value of 0.001, which is less than the predetermined threshold of 0.05, further supports the acceptance of the hypothesis. This figure implies a positive correlation between farmers' engagement within an organization and the effectiveness of production input utilization. Research indicates that the participation of farmers in agricultural organizations has a beneficial effect on enhancing the utilization of production inputs, including production quality and income. Farmer organizations or groups provide product marketing, market information access, and extension services, all contributing to increased income and production quality. In addition, these services also play a role in increasing the use of good agricultural practices and new technologies, which in turn increases farmers' productivity and income [69].

Moreover, the findings demonstrated a strong and statistically significant correlation between the variable Family Resources (FRR) and Production Input Application (APR), with a coefficient of 0.923 and a t-statistic of 12.14. This figure suggests that an augmentation in the resources possessed by the family can substantially enhance the utilization of production inputs in agricultural endeavors. The high coefficient value indicates that there is a strong correlation between the two variables, where family resources such as financial capital, access to land, availability of labor, and education level have a great influence in enabling farmers to adopt and apply agricultural technology, use of fertilizers, quality seeds, and more efficient farming methods. With a p-value of <0.001, which is much lower than the 0.05 threshold, this result confirms that the relationship between family resources and the use of production inputs is not coincidental but rather has a strong statistical basis, suggesting that improving family resources is vital in improving agricultural efficiency and productivity.

On the other hand, this study showed a negative and significant relationship between farmers' involvement in an organization (FRR) and Crop Management (CMR), with a coefficient of −0.123 and a t-statistic of −4.427, suggesting complex dynamics in social interaction and farm management. Intensive involvement in farmer organizations/groups limits the time or resources available for farmers to implement optimal crop management practices or may direct their focus to broader activities than crop-specific management. It may also reflect that the advice or practices advocated by the organization are not always in line with the best or most efficient crop management techniques for local farming conditions. This research is a reminder of the importance of considering social aspects in farm management strategies, as discussed in research by Pretty [70], who explored how institutions and social networks influence sustainable farming practices, as well as by Padel [71], who highlighted the impact of organizational membership on agricultural technology adoption.

The results showing a positive and significant relationship between Family Resources (FRR) and Crop Management (CMR), with a coefficient of 0.240 and a t-statistic of 3.078, underscore the importance of family resources in improving crop management practices. This positive coefficient indicates that increases in the resources available to farm families, such as financial capital, access to information, education, and labor, directly contribute to their ability to adopt and implement more effective and sustainable crop management methods. This result is in line with the findings by Soule et al. [72], who found that better access to resources enables farmers to apply agricultural technologies to increase productivity. In addition, Barret et al. [55] research also showed that family social and economic capital plays a role in facilitating the adoption of improved agricultural practices, underscoring that family resources affect financial capacity and access to agricultural knowledge and technology. These results reinforce the argument that interventions to improve family resources can be an effective strategy to support better crop management, which in turn can improve agricultural sustainability and productivity.

Furthermore, the research findings also demonstrated a statistically significant and favorable correlation between Production Input Application (APR) and Crop Management (CMR), with a coefficient of 0.777 and a t-statistic of 9.635, confirming that improvements in the use of production inputs such as fertilizers, pesticides, quality seeds, and agricultural technologies, contribute significantly to the effectiveness of crop management. This study illustrates how proper and efficient application of production inputs can improve crop management practices, increasing agricultural productivity and sustainability. This result aligns with the findings by Pannel et al. [73], who stated that adopting innovative and sustainable production inputs is vital to improving resource use efficiency and agricultural yields. In addition, research by Pretty & Bharucha [74] also emphasized the importance of

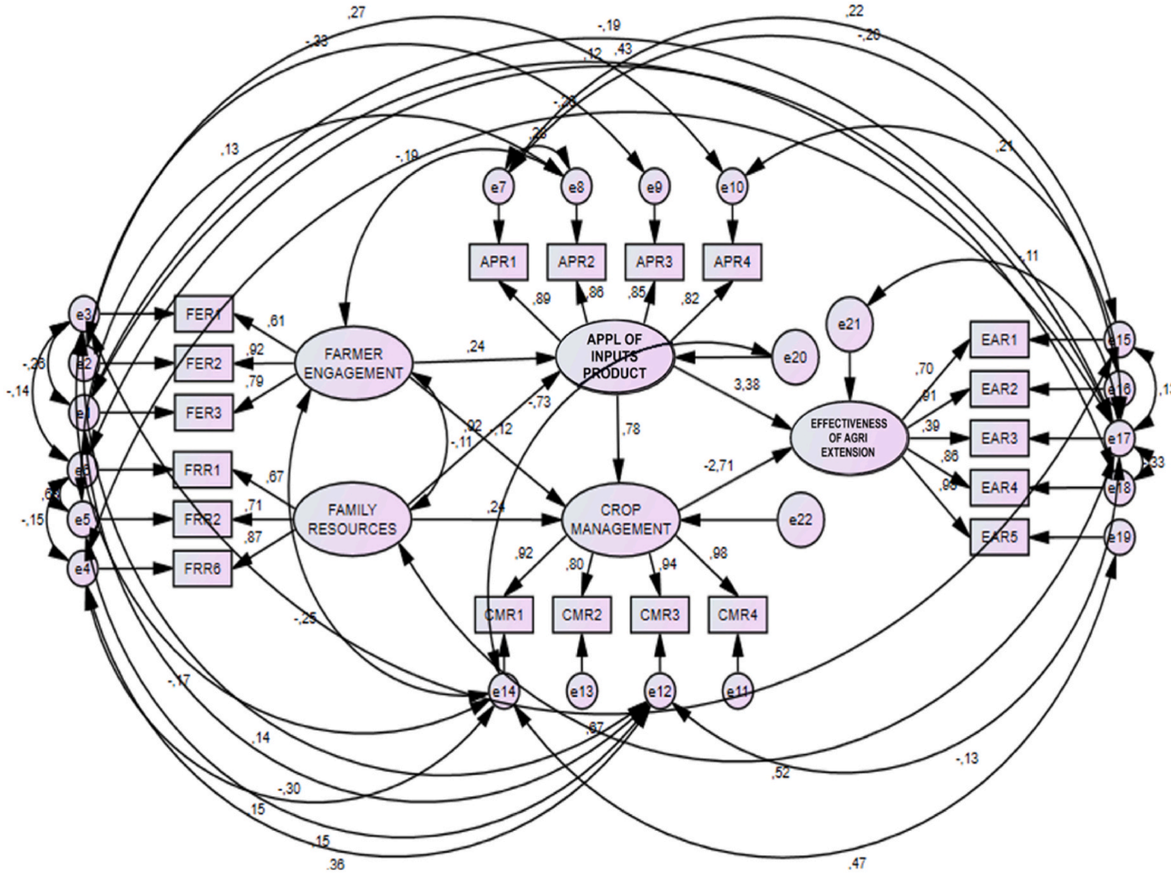

Fig. 6. Path diagram after index modification.

Table 6
The goodness of fit model after covariance index modification.

Index	*Goodness of Fit*	*Cut Off Value*	Description
p-value	0.104	≥0.05	*Good of Fit*
CMIN/DF	1.170	≤2.00	*Good of Fit*
RMSEA	0.033	≤0.08	*Good of Fit*
TLI	0.991	≥0.90	*Good of Fit*
CFI	0.994	≥0.90	*Good of Fit*
NFI	0.959	≥0.90	*Good of Fit*
PNFI	0.634	the bigger the fit	*Good of Fit*

Table 7
R-square test results.

Endogenous Variables	R-square
APR	0.863
CMR	0.989
EAR	0.924

Table 8
Interpretation of the R-square coefficient.

Coefficient Interval	Relationship Level
0.800 - 1.000	Very Strong
0.600 - 0.799	Strong
0.400 - 0.599	Strong Enough
0.200 - 0.399	Weak
0.000–0.199	Very Weak

knowledge-based management of production inputs to improve farmer welfare and environmental sustainability. These results suggest that policies and interventions to support farmers accessing and using production inputs effectively can significantly impact crop management and overall agricultural productivity.

Similarly, the findings indicate a positive and significant relationship between the variable Production Input Application (APR) and the Effectiveness of Agricultural Extension in Rice Farming (EAR), with a coefficient of 3.383 and a t-statistic of 5.87, highlighting the importance of appropriate production inputs in enhancing the benefits of agricultural extension. The high coefficient indicates that the efficient use of production inputs, such as high-quality seeds, appropriate fertilizers, and modern agricultural technology, significantly improves the effectiveness of agricultural extension programs. This result is because agricultural extension often focuses on introducing and adopting best agricultural practices, which require appropriate production inputs for implementation. Research by Danjumah [75] also underscores that the success of agricultural extension in improving agricultural productivity depends on knowledge transfer and farmers' ability to access and use production inputs effectively. These findings validate that in enhancing the efficiency of agricultural extension, particularly in rice cultivation, it is imperative to facilitate farmers' acquisition of high-quality and pertinent production resources.

Lastly, the results showing a negative and significant relationship between crop management (CMR) and Effectiveness of Agricultural Extension in Rice Cultivation (EAR), with a coefficient of −2.712 and a t-statistic of −4.841, reveal that improvements in effective crop management, which includes practices such as proper variety selection, optimal use of fertilizers and pesticides, and efficient irrigation techniques reduce the need for agricultural extension as farmers are already implementing best practices independently. In other words, farmers

Table 9
The results of direct effect hypothesis testing.

Hypothesis	Path	Standardized Coefficient	S.E	Critical Ratio	p-value	Description
H1	FER→APR	0.244	0.048	4.405	[a]	Significant
H2	FRR→APR	0.923	0.036	12.14	[a]	Significant
H3	FER→CMR	−0.123	0.040	−4.427	[a]	Significant
H4	FRR→CMR	0.240	0.061	3.078	0.002	Significant
H5	APR→CMR	0.777	0.133	9.635	[a]	Significant
H6	APR→EAR	3.383	0.503	5.87	[a]	Significant
H7	CMR→EAR	−2.712	0.295	−4.841	[a]	Significant

Note.
[a] p-value <0.001.

Table 10
The results of indirect effects hypothesis testing.

Hypothesis	Path	Sobel Test Statistic	Std. Error	p-value	Description
H8	FER → APR → EAR	4.055	0.203	[a]	Significant
H9	FRR → APR → EAR	6.505	0.479	0.000	Significant
H10	FER → CMR → EAR	2.916	0.114	0.003	Significant
H11	FRR → CMR → EAR	−3.617	0.179	[a]	Significant
H12	APR → CMR → EAR	−4.930	0.427	[a]	Significant

Note.
[a] p-value <0.001.

who manage their crops very well may feel they benefit less from extension, as they already have sufficient knowledge or resources. This finding is consistent with research by Davis et al. [59], who found that the effectiveness of agricultural extension often depends on the knowledge and resources farmers already have before receiving an extension. In addition, a study by Wossen et al. [76] showed that adopting agricultural innovations can be influenced by various factors, including existing crop management skills, which can reduce farmers' dependence on extension. These results emphasize the importance of tailoring agricultural extension programs to farmers' existing crop management knowledge and practices to increase their effectiveness in rice cultivation.

Family resources and crop management are closely linked and play a significant role in determining the success of agricultural extension. Family resources, such as education level, farming experience, access to information, and the number of family members, can influence farmers' ability to absorb, understand, and apply new information and technologies provided through extension provides better resources tend to be better able to adopt better farming practices, thus increasing the effectiveness of extension. Meanwhile, good crop management, including variety selection, proper use of fertilizers and pesticides, and appropriate cultivation techniques, is critical to improving agricultural productivity and sustainability. Agricultural extension is important in providing farmers with the knowledge and skills needed to implement good crop management.

This relationship has important implications for Indonesia's agricultural extension policy. Extension programs need to be designed with a family-based approach, recognizing the role and dynamics of families in agricultural decision-making. In addition, farmers' access to resources that support good crop management, such as improved seeds, fertilizers, agricultural technology, and agricultural education and information, needs to be improved. Extension should also be tailored to farmers' specific needs and conditions, including considering their family resources. Strengthening the capacity of agricultural extension workers and collaboration with research institutions are also important to ensure effective technology transfer. Lastly, regular evaluation and monitoring of extension programs is needed to measure their impact and make necessary improvements. By understanding and implementing these policy implications, it is hoped that agricultural extension in Indonesia can be more effective in empowering farmers, increasing agricultural productivity and sustainability, and ultimately improving farmers' welfare and national food security.

In Table 10, the indirect effect analysis provides important insights into how various factors mediate the relationship between independent and dependent variables in the context of the effectiveness of rice agricultural extension. Firstly, the mediation test involved the variables Farmer Engagement (FER) and Family Resources (FRR) influencing the Effectiveness of Agriculture Extension (EAR) through Application Product Inputs (APR). Both FER and FRR showed significant mediation by APR, with significant Sobel statistics and low p-values, suggesting that managing agricultural product inputs is a crucial aspect that links farmer engagement and family resources to the effectiveness of agricultural extension interventions. This condition confirms the importance of ensuring that farmers have access to and can utilize appropriate agricultural inputs as part of extension programs to improve farmers' production outcomes. Furthermore, Crop Management (CMR) is a significant mediator between FER and FRR to EAR. This mediation suggests that effective crop management is another key in linking farmer engagement and family resources with effective agricultural extension. In line with this result, extension programs that focus on improving crop management capacity can improve the overall effectiveness of agricultural extension programs.

In addition, the negative Sobel statistic value in the last mediation test (APR influences EAR through CMR) that remains significant indicates that this relationship is statistically significant but in the opposite direction of what is expected. This could imply that the more product inputs are applied, the greater the inclination for less optimal crop management, thereby reducing the efficiency of extension initiatives. These findings demonstrate the importance of components such as product input management and crop management in maximizing the effectiveness of agricultural extension programs, emphasizing the need for an integrated approach that considers the interactions between the various factors that influence rice farming outcomes.

6. Conclusions and recommendations

The objective of this study was to analyze the determinants that impact the effectiveness of agricultural extension services on rice cultivation in Bantaeng Regency, located in the South Sulawesi Province of Indonesia. The participants in this study consisted of 155 rice farmers who engaged in rice cultivation during the most recent planting season of 2022. The process of data collecting involved implementing organized interviews with specifically chosen respondents. Afterward, the data were examined using the Structural Equation Modeling (SEM) model. Testing the direct effect hypothesis results show a significant relationship between variables. The FER variable has a positive effect on APR, which indicates that farmers' involvement in an organization will increase the use of production inputs. Family resources also positively impacted APR, highlighting the importance of resources in increasing production input utilization. However, FER has a negative impact on CMR, indicating that intense involvement in farmer organizations may hinder optimal crop management practices.

On the other hand, FRR positively impacts CMR, emphasizing the role of resources in improving crop management. APR positively impacts CMR, indicating that effective use of production inputs will improve crop management. Finally, APR and FER were found to influence EAR, while CMR negatively influenced EAR positively. Testing the indirect effect hypothesis shows that APR and CMR mediate the relationship between FER, FRR, and EAR, emphasizing the importance of agricultural inputs and crop management in improving the effectiveness of agricultural extension programs.

The practical policy recommendation to improve the effectiveness of agricultural extension in Indonesia is to adopt a participatory approach that empowers farmers. Actively involve them in the entire extension process, from planning to evaluation, and encourage their participation in farmer groups and agricultural organizations. In addition, it is important to strengthen the resources of farming families, including access to education, training, capital, and technology, and pay attention to gender equality. Furthermore, extension services need to focus on practical training on crop management and modern agricultural technologies, including the use of efficient and environmentally friendly production inputs. Utilization of information and communication technology is also important to increase the reach and effectiveness of extension. In addition, the capacity and professionalism of agricultural extension workers need to be improved through continuous training, and a strict monitoring and evaluation system should be implemented. Finally, cross-sector collaboration between extension agencies, research, universities, and the private sector must be encouraged to ensure the effective transfer of agricultural technologies and innovations. With this holistic approach, agricultural extension in Indonesia is expected to be more effective in empowering farmers, increasing agricultural productivity and sustainability, and supporting farmers' welfare and national food security.

Limitations of the research

This research was found to have some shortcomings. The research sample size was comprised of 155 rice farmers, which fell into the medium number in the SEM model. It is possible that the findings would have been marginally different if the study's sample size had been larger. The scope and sample size were restricted because the research study was self-funded and had a limited budget. This condition prevented the inclusion of a large sample size.

CRediT authorship contribution statement

Muslim Salam: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization. **Muhammad Hatta Jamil:** Supervision, Project administration, Methodology, Conceptualization. **A. Nixia Tenriawaru:** Supervision, Project administration, Methodology, Conceptualization. **Nitty Hirawaty Kamarulzaman:** Writing – review & editing. **Siti Hardiyanti Syam:** Writing – original draft, Visualization, Software, Methodology. **Rahmadanih:** Supervision, Methodology, Supervision, Methodology. **Anggun Ramadhani:** Writing – original draft, Software, Data curation. **Anny Melody Bidangan:** Writing – original draft, Software, Conceptualization. **Ahmad Imam Muslim:** Writing – review & editing. **Hamed Noralla Bakheet Ali:** Writing – review & editing. **Muhammad Ridwan:** Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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