Can agricultural extension enhance the climate resilience of smallholder famers? Evidence from West Java, Indonesia

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Abstract. This study explored the impact of agricultural extension and livelihood capital on the resilience of rice farmers in the food barn areas of the Karawang and Subang districts of West Java Province, Indonesia. These regions are crucial for national food security and are becoming increasingly vulnerable to climate risks. Using a mixed-methods approach, we collected data from 100 rice farmers to evaluate how agricultural extension influences three key dimensions of resilience: stabilization, adaptation, and transformation. The findings of this study provide a preliminary analysis showing that the implementation of extension by the government alone does not significantly impact farmers' resilience (p=0.7). The resilience capacity of rice farmers in the low category in both districts. However, a pluralistic approach could enhance farmer resilience regarding stabilization and adaptation capacity. Human and social capital significantly influenced rice farmer resilience (p=0.00 and p=0.007, respectively). The findings of this study underscore the importance of pluralistic extension models for enhancing farmers' resilience to climate change. This study contributes to understanding the significance of pluralistic extension services through dynamic interactions with livelihood capital, which can bolster the climate resilience of smallholder farmers in Southeast Asia.

1 Introduction

Climate change has been identified as the most critical environmental and humanitarian crisis in the 21st century [1]. The agricultural sector is the most affected and heavily reliant on local climatic conditions and natural resources [2]. Moreover, this sector play a significant role in greenhouse gas emissions and complicate further challenges. Rice farming is among the most vulnerable crops to climate change [3]. This phenomenon has resulted in diminished rice yields, adversely affecting farmers' incomes and creating substantial challenges for nations whose economies are agriculture dependent [4]. The immense pressure of climate change on rice farmers necessitates efforts to enhance understanding and strengthen resilience, thus

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enabling greater adaptability, which is characterized as the capacity to maintain system functions despite increasingly complex shocks and stresses and is supported by the ability to stabilize, adapt, and transform [5].

Agricultural extension functions as a pivotal instrument for fortifying the resilience of farming systems by facilitating on-farm enhancements, such as optimizing labour and financial management [6]. Agricultural extension is a multifaceted learning process catalyzing community development [7]. Resilience is also closely related to livelihood capital, emphasizing how human, social, and physical capital improves income, well-being, and food security [8]. Integrating the livelihood capital approach and agricultural extension with resilience thinking can deepen our understanding of livelihood dynamics.

Considering the imperative to identify effective strategies that enhance rice farmers' resilience to climate change, particularly given the considerable public investment in agricultural extension services, it is imperative to evaluate the impact of these services and the livelihood capital approach on farmers' capacity to adapt to and withstand the effects of climate change. However, there is a paucity of research examining the combined effects of agricultural extension, human capital, social capital, and physical capital on farmers' resilience to climate change. Integrating extension approaches and livelihood capitals within a pluralistic extension framework is a potential solution to this knowledge gap. This study employs the resilience framework described by Meuwissen to address this gap by posing and answering the following questions: (i) Do agricultural extension, human capital, social capital, and physical capital improve rice farmers' resilience to climate change? (ii) Which resilience capacities are enhanced by agricultural extension, human capital, social capital, and physical capital?

2 Research method

2.1 Research framework

Meuwissen developed a five-step framework to assess agricultural resilience, which is comprised of the following five steps: (i) What is the resilience of what?; (ii) resilience to what?; (iii) resilience to what purpose?; (iv) what is the resilience capacity?; and (v) what enhances resilience? In this study, the focus will be limited to the fourth and fifth stages of the aforementioned framework. The study employed three criteria to assess resilience (Fig. 1): stabilization capacity, adaptation capacity, and transformation capacity.

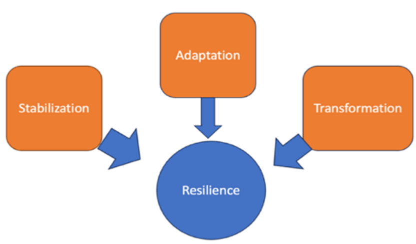

Fig. 1. Three resilience capacities, namely stabilization, adaptation, and transformation capacity. This image is adapted from Meuwissen.

A multitude of internal and external factors contribute to farmer resilience. The sustainable livelihood approach is a comprehensive framework elucidates these factors . This study focuses on three specific types of capital: human, social, and physical. The investigation encompasses how these aspects of capital and the delivery of agricultural extension services impact rice farmers' resilience and sustainability of their farming business. The operational framework of this study is illustrated in Fig. 2.

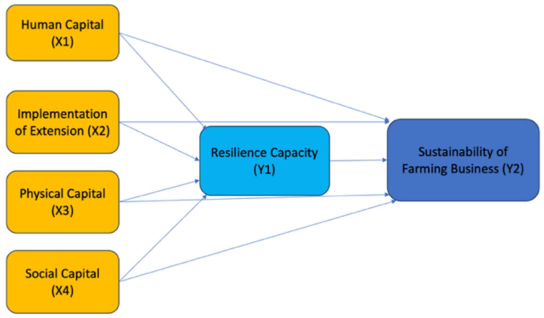

Fig. 2. The operational framework of this research

2.2 Data collection and procedure

This study was conducted in two districts in West Java Province: Karawang District, an intensive agricultural area, and Subang District, a semi-intensive agricultural area. The research location in Karawang District is in Cilamaya Wetan Sub-District and Cilamaya Kulon Sub-District, while for Subang District, the research location is in Pabuaran Sub-District and Kalijati Sub-District. The selection of research locations was carried out purposively, considering the agricultural typology in the area, namely, intensive agriculture (Karawang District) and semi-intensive agriculture (Subang District). This selection was made because West Java is a province that serves as the basis of the national food barn, which faces the high risk of economic damage due to extreme weather and climate change. Karawang District and Subang District are the second and third-largest rice-producing regencies in West Java. The Indonesian government has designated both districts as priority areas in the agricultural sector to enhance climate resilience.

The study employed a mixed-method approach and was conducted over three months, from September to November 2024. A simple random sampling method was used to select the respondents. The participants were rice farmers who met the following criteria: a) cultivated rice during at least the last planting season of 2023, b) experienced flooding or drought in their rice fields within the past five years, and c) owned rice field areas of less than two hectare. Randomly selecting participants was conducted without regard for demographic or other characteristics that could influence the results. The required sample size was determined using the Cochran formula:

$$n = \frac{Z^2 pq}{e^2} \quad (1)$$

Where n represents the requisite number of samples, Z denotes the value from the normal distribution for a 95% confidence interval, which is 1.64, p and q signify the probabilities of 50% for correct and incorrect outcomes, respectively, and e indicates the sampling error rate, set at 10%. The quantities of the samples acquired for this study were as follows:

$$n = \frac{Z^2 pq}{e^2} = \frac{(1{,}96)^2\,(0{,}5)(0{,}5)}{(0{,}10)^2} = 96{,}04$$

The Cochran formula indicated that a minimum of 96 respondents were required for this investigation. This study selected 100 rice farmers in the Cilamaya Wetan and Cilamaya Kulon sub-districts in Karawang District and the Pabuaran and Kalijati sub-districts in Subang District as research respondents. In-depth interviews were conducted with target farmers and agricultural extension workers.

2.3 Data analysis

This study employs a dual approach, integrating quantitative and qualitative analyses, which utilizes inductive statistical methods, whereas qualitative analysis adopts an abductive approach. Survey data were examined using Structural Equation Modelling (SEM) with Structural Partial Least Squares (Smart PLS) 4.0 to identify the factors influencing resilience capacity and the sustainability of farming businesses. Quantitative data collected through the field questionnaires were measured on an ordinal scale using the symbols 1, 2, 3, and 4. These data were then statistically analyzed to determine each variable's median and standard deviation values, and class intervals were established and categorized as very low, low, high, and very high. Ordinal data (with a minimum score of 1 and a maximum score of 4) were transformed into interval or ratio scale data to conduct a parametric statistical analysis.

2.4 Ethics

The Ethical Committee on Social Studies and Humanities National Research and Innovation Agency Indonesia approved this study. Ethical clearance approval: 759/ KE.01/SK/09/2024.

3 Results and discussion

3.1 Respondent characteristic

Table 1 presents the essential characteristics of the respondents, revealing that 84% were male farmers, a figure that significantly exceeds the 16% representation of female farmers. This observation aligns with the findings reported by Baffour-Ata *et al.* [9], which indicate a global predominance of male farmers over female farmers. This phenomenon is further corroborated by the 2023 Indonesian agricultural census results, which documented that 86% of Indonesian rice farmers are male. This discrepancy is primarily attributed to men's greater access to agricultural labour, equipment, extension services, and farming-related financing than women. The respondents were primarily aged 52-73 (66.40%), followed by those aged 39-51 (25.30%). The smaller proportions of the younger (26-38 years, 3.56%) and older (74-86 years, 4.74%) age groups suggest that rice farming is predominantly managed by middle-aged and older individuals, reflecting the low interest of young people in this field. Most respondents had received only primary education (29.05%) or junior high school (21.23%), 45.25% had attained senior high school education, and 4.47% had pursued higher education.

Table 1. Respondent characteristics

Category	Frequency (n= 100)	Percentage
Sex		
Male	84	84
Female	16	16
Age (in years)		
26-38	9	3.56
39-51	32	25.30
52-73	56	66.40
74-86	3	4.74
Level of Formal Education		
Elementary School	52	29.05
Junior High School	19	21.23
Senior High School	27	45.25
Tertiary/Higher Education	2	4.47
Marital Status		
Single	6	6
Married	94	94
Rice Farming Experience (in years)		
1-11	30	13.57
12-23	32	28.96
24-35	25	33.94
36-47	13	23.53
Area of Cultivated Land (in hectares)		
0,11-0,61	31	14.83
0,62-1,12	42	40.19
1,13-1,63	14	20.10
1,64-1,99	13	24.88
Years of Extension		
1-13	62	44.29
14-26	37	52.86
27-39	0	0
40-52	1	2.86

Most respondents reported participating in agricultural extension for a period ranging from one to 13 years (44.29%) and 14 to 26 years (52.86%). These data suggest that farmers have been engaged in extension practices for an extended period. This finding is encouraging because agricultural extension has the potential to play a vital role in addressing the challenges posed by climate change by serving as a conduit for climate information, facilitating technology transfer, and fostering capacity building.

3.2 Rice farmer resilience strategy

As illustrated in Fig 3, the research findings indicates that only 10% of farmers in Karawang District and 18% in Subang District cultivated more than one rice variety. Planting diverse varieties has been demonstrated to enhance resilience to climate-related risks. The utilization of climate-resistant rice varieties remains limited, with only 10% of farmers in Karawang District and 18% in Subang District. Varieties which are resistant to drought and flooding, are crucial for adapting to climate variability, and research has demonstrated that farmers who utilize climate-resistant varieties experience more stable yields, even during periods of extreme climatic conditions [10]. To enhance resilience against climate change, it is imperative that extension services actively promote the adoption of climate-resistant varieties.

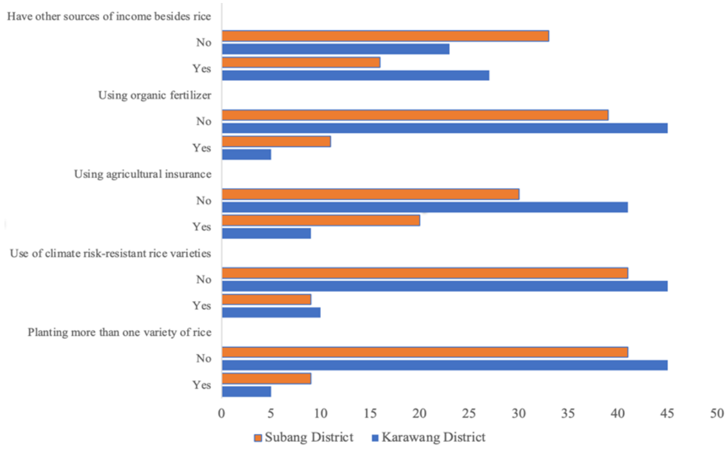

Fig. 3. Rice farmer's resilience strategy

The implementation of agricultural insurance in the Karawang and Subang districts revealed that only 18% of farmers in the Karawang district and 40% of farmers in Subang district. This finding suggests a need for increased awareness initiatives to promote insurance benefits. Implementing agricultural insurance is crucial for increasing farmers' resilience to climate risks [11]. Concerning the income diversification strategy, it was observed that farmers in Karawang District possess a significant number of income sources beyond agriculture, with a percentage as high as 54%. In comparison, only 32.65% of farmers in Subang reported similar income sources.

3.3 Rice farmer resilience capacity

The resilience capacity of rice farmers in the Karawang District was lower than that of rice farmers in the Subang District (Fig. 4). Karawang District has a stabilization capacity with an index value of 51.89. In contrast, the Subang District had an index value of 71.34. Nonetheless, both districts fall within the high-capacity category of stabilization capacity. This indicates the ability of the farmers to withstand significant pressure in these two areas. Regarding adaptation capacity, rice farmers in Karawang District had an index of 25.5, compared to 36.6 for those in Subang District. Farmers in both research locations exhibited low adaptation capacity. This low adaptation capacity suggests that while there are adaptation efforts, they are executed spontaneously and reactively rather than strategically and holistically [12].

Reactive adaptation is attributed to several factors, including farmers' limited access to and ability to interpret climate data, trust in extension services, and reluctance to adopt more sophisticated innovations. Regarding transformation capacity, rice farmers in Karawang District exhibited an index of 21.1, which is regarded as very low. In contrast, farmers in the Subang District demonstrate an index of 25.5, also classified as low. The transformation capacity in both research locations was the lowest compared to other resilience capacities. Furthermore, there was no evidence of successful transformation of rice farming in either research location. In general, the resilience capacity of the rice farmers in both districts were low.

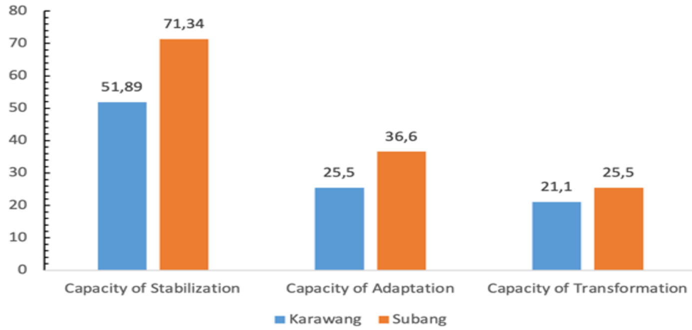

Fig. 4. Rice farmers resilience capacity

3.4 Measurement model evaluation

Table 2 shows an evaluation of the measurement model using smart PLS. The research findings indicate that various dimensions influence farmers' resilience capacity, including human capital, physical capital, social capital, extension services, and farming businesses' sustainability. The human capital dimension, which encompasses non-formal education and farming motivation, significantly contributes. Extension services also proved to play a crucial role, with indicators such as the uniformity of materials and competence of extension workers showing high efficiency (Composite Reliability 0.899). Pluralistic and relevant extension services can help farmers understand climate risks and adopt adaptive technologies. Additionally, physical capital, which includes access to agricultural facilities and technological information, significantly enhanced farmers' adaptive capacity (AVE = 0.727). Investment in climate-resilient infrastructure and digital platforms is essential to support data-driven decision-making by farmers.

Table 2. Measurement model evaluation with Smart PLS

Variable	Indicator	Outer Loading	Cronbach's Alpha
Human Capital	Non-formal education	0.770	0.020
	Motivation to farm rice	0.738	
Implementation of Extension	Suitability of extension materials	0.805	0.876
	Accuracy of extension methods	0.724	
	Timeliness of extension	0.708	
	Competence of extension workers	0.767	
	Farmer participation	0.779	
	Extension planning	0.704	
	Evaluation of extension	0.752	
Physical capital	Accessibility of agricultural facilities and infrastructure	0.726	0.678
	Accessibility of information technology	0.963	
Social capital	Social network	0.734	0.584
	Group support	0.847	
Resilience capacity	Stabilization capacity	0.780	0.680
	Adaptive capacity	0.709	
	Transformation capacity	0.850	
Sustainability of farming business	Economic aspects	0.854	0.715
	Social aspects	0.720	
	Environmental aspects	0.807	

Social capital, defined as social networks and group support, enhances farmers' resilience by facilitating collaboration and resource sharing, particularly in the face of complex climate risks. However, the relatively low AVE value (0.433) indicated the need to strengthen social capital. Conversely, the resilience capacity dimension revealed that the third indicator exhibited outer loading ranging from 0.709 to 0.850. This variable exhibited adequate reliability and validity (Cronbach's alpha = 0.680, Composite Reliability = 0.824, AVE = 0.611), thereby underscoring the model's capacity to elucidate farmers' resilience capacity. Farming sustainability, encompassing the economic, social, and environmental dimensions, is also imperative in fortifying resilience. Of note is the economic aspect, which exhibited the most substantial influence (an outer loading of 0.854). This finding underscores the significance of income diversification and production efficiency in mitigating farmers' vulnerability to climate change. An integrated approach, which includes strengthening extension services, investing in infrastructure, and fostering multi-stakeholder collaboration, conceptually referred to as pluralistic extension, is essential for holistically enhancing farmers' resilience capacity.

3.5 Structural model evaluation

Table 3 indicates that the human capital variable positively influences resilience capacity (path coefficient = 0.325, $p < 0.001$), highlighting its significant role in enhancing farmers' ability to adapt to climate change. However, its impact on the sustainability of farming businesses is insignificant ($p = 0.111$). This suggests that while human capital, including education, skills, and motivation, can empower farmers to cope with the challenges of climate change, ongoing education and training in climate-smart agriculture remain essential. The research findings also reveal that implementing extension services does not significantly influence resilience capacity ($p = 0.700$) or sustainability of agricultural businesses ($p = 0.103$). This underscores the extension practices carried out by government extension workers and emphasizes the need to ensure their competence as the materials and methods they employ must effectively address climate adaptation needs. Strengthening extension efforts should involve implementing a pluralistic and participatory approach to encourage farmers and other stakeholders to engage in climate-sensitive extension initiatives. Qualitative findings support this, as there is evidence that farmers learn from one another and that social capital networks are related to climate change adaptation.

Table 3. Hypothesis testing results among study variables

Relation	**Coefficient path**	***p-values***	**Description**
Human Capital → Resilience Capacity	0.325	0.000	Significant
Human Capital→ Sustainability of Farming Business	0.149	0.111	Not Significant
Implementation of Extension → Resilience Capacity	0.038	0.700	Not Significant
Implementation of Extension→Sustainability of Farming Business	0.160	0.103	Not Significant
Physical Capital→Resilience Capacity	-0.109	0.352	Not Significant
Physical Capital→Sustainability of Farming Business	0.241	0.006	Significant
Social Capital→Resilience Capacity	0.301	0.007	Significant
Social Capital→Sustainability of Farming Business	0.217	0.016	Significant
Resilience Capacity→ Sustainability of Farming Business	0.302	0.000	Significant

Physical capital, including access to resources and infrastructure, significantly impacts the sustainability of farming businesses (path coefficient = 0.241, $p = 0.006$), although it does not directly influence resilience capacity ($p = 0.352$). This underscores the importance of providing infrastructure, such as irrigation systems, storage facilities, and technological devices, to support long-term goals. The farmer resilience variable demonstrates a direct relationship between resilience capacity and the sustainability of the farming business (path coefficient = 0.302, $p < 0.001$). This indicates that resilience capacity plays a crucial mediating role in the sustainability of rice-farming businesses.

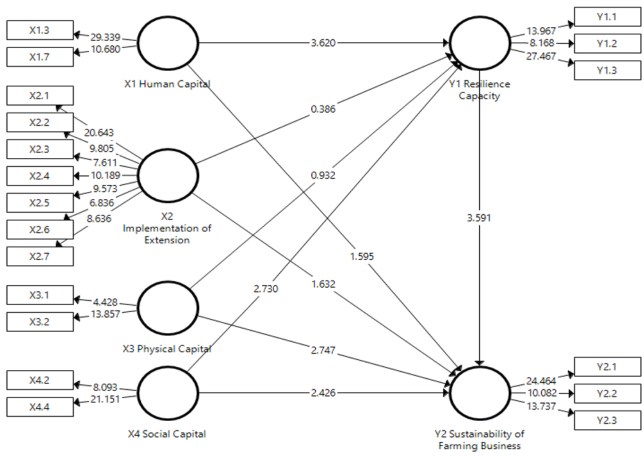

Fig. 5. Inner model test results

Fig 5 displays the results of the internal model test, highlighting the significance of a holistic approach to enhancing farmers' resilience to climate change. Human and social capital play crucial roles in building resilience, whereas physical capital significantly affects the sustainability of farming business. This aligns with research findings that resources, accessibility, and social capital influence community resilience [13]. The extension implementation model requires strategic updates. Extension efforts cannot rely solely on government services but must adopt a consistently pluralistic approach. A blend of stabilization, adaptation, and transformation strategies is essential for developing farmers' resilience and achieving long-term stability in agricultural systems.

3.6 Implications for extension design and practice

The research results indicate that relying solely on government extension workers for implementation does not significantly affect farmer resilience. However, if they refine their approach, all the developed models can be implemented to enhance rice farmers' climate resilience. Conversely, the findings show that rice farmers place greater trust in other farmers' and individuals' information and knowledge within their social capital networks. This highlights the critical need to implement a pluralistic extension approach and to ensure adequate policy support to facilitate adoption. Similar findings have been observed in other studies regarding the low trust in government extension workers and farmers' greater trust in other pioneering farmers [14].

The research findings also indicate an increase in stabilization resilience and a slight increase in adaptive capacity but show no evidence of an increase in transformation capacity. For a farming system to undergo substantial changes in its internal structure, feedback mechanisms require more than simply engaging farmers in extension activities. Agricultural extension can help enhance transformation capacity with broader policy support for farmers.

Farmers often decide how to adapt to climate change pressure by consulting with other farmers. Government extension officers do not play a significant role in this process. However, this presents a significant opportunity to implement agricultural extensions using a pluralistic approach. The high capacity for stabilization, along with low adaptation and transformation capabilities, suggests that most changes are short-term and reactive.

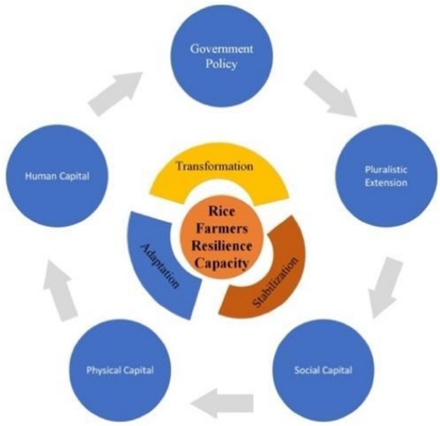

Fig. 6. The wheel of increasing rice farmer resilience through the implementation of pluralistic extension and a holistic approach

Fig 6 illustrates the wheel strategy for comprehensively enhancing rice farmer resilience, ensuring that resilience is not solely reactive but strategic and holistic, thus enabling adaptation and transformative capacity. This study highlights the significance of human, social, and physical capital in strengthening farmers' resilience and the sustainability of their farming businesses. These three types of capital, combined with the execution of pluralistic extensions supported by robust government policies, have the potential to foster holistic and strategic resilience among rice farmers. This approach enables farmers to enhance their adaptation and transformation capabilities in response to climate change. The developed extension model must consider and integrate all these components. This aligns with research findings that emphasize the necessity of approaches and policies that enhance the role of extension services, and farmer organizations in strengthening the resilience of small-scale farmers [15].

4 Conclusion

Implementation of the extension by the government alone did not significantly affect farmer resilience. However, a pluralistic approach could enhance farmers' resilience regarding stabilization and adaptation capacity. Human and social capital significantly influences rice farmers' resilience. Both forms of capital are linked to implementing pluralistic extensions that can serve as models for boosting farmers' resilience to climate change. With strong policy support, implementing pluralistic extensions that include human, social, and physical capital can strengthen rice farmers' resilience to climate change.

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