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RESEARCH ARTICLE

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The Influence of Agricultural Extension Services and Livelihood Capitals on Farmers' Climate Resilience in West Java, Indonesia: A Structural Equation Modelling Approach

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ABSTRACT

The agricultural sector is vulnerable to the impacts of climate change. Climate change has affected the livelihoods of smallholder farmers, particularly in agriculturally based developing countries. This study examines the impact of agricultural extension services and various forms of livelihood capital on the climate resilience and farm sustainability of rice farmers in West Java, Indonesia. A total of 371 respondents from Karawang and Subang Regencies were surveyed using a structured questionnaire that covered farmers engaged in intensive and semi-intensive rice production systems. The study employed Structural Equation Modeling using Partial Least Squares (SEM-PLS) to assess the direct and indirect effects of human, social, natural, financial, and physical capitals, as well as extension services, on resilience capacity and farm sustainability. The results show that human capital, natural capital, social capital, financial capital, and extension services all have a significantly positive effect on resilience capacity. In turn, resilience capacity is a key mediating variable contributing to farm sustainability. Furthermore, the Importance-Performance Map Analysis (IPMA) reveals that financial and natural capital are high-priority areas for intervention due to their strategic influence and current performance gaps. These results underscore the need to enhance farmers' access to inclusive and adaptive financial services, improve natural resource governance, and strengthen the quality and contextual relevance of agricultural extension services. The study recommends a shift toward a pluralistic and resilience-oriented extension model that integrates livelihood assets and climate adaptation strategies to build sustainable and climate-resilient farming systems.

Introduction

The agricultural sector contributes to food security, job creation, and increasing farmers' incomes [1], however, this sector is vulnerable to the impacts of climate change. Climate change has affected the livelihoods of smallholder farmers, particularly in agriculture-based developing countries [2]. As an agriculture-based country, Indonesia is vulnerable to climate change impacts, such as floods, droughts, shifts in rainfall patterns, and rising temperatures [3]. Indonesia ranks third in the world in terms of the highest exposure to climate risks, particularly floods and droughts, which threaten agricultural production and food security [4,5]. Several reports indicate that temperatures in Indonesia are projected to rise between 0.8 °C and 1.4 °C by the year 2050 [6]. Data from *Badan Pusat Statistik* (BPS) show that the country has experienced a decline or stagnation in food production over the past two years. BPS reported that rice production decreased by 1.12 million tons (2.05%), from 54.75 million tons of *Gabah Kering Giling* (GKG) in 2022 to 53.63 million tons in 2023 [7]. The harvested rice area also declined by 256 thousand hectares (2.45%), from 10.45 million hectares in 2022 to 10.20 million in 2023. This trend is consistent with findings from the 2023

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Agricultural Census conducted by BPS [8], which revealed that the number of farming households cultivating rice declined by 2.18 million between 2013 and 2023.

The pressures of climate change have led to stagnation in achieving Sustainable Development Goals (SDGs) targets [9] and have also increased the vulnerability of farming households [10]. This highlights the need to design agricultural governance through a resilience-oriented perspective. Applying a resilience lens enables farmers and the agricultural sector to develop resilience capacities, which ultimately support the achievement of the SDGs despite ongoing pressures [9]. Enhanced resilience also helps reduce social and economic vulnerabilities affecting farmers' welfare and livelihoods [11]. Improved farmer resilience contributes to the sustainability of farming [12], across economic, social, and environmental dimensions [13]. The ability of farmers to cope with both short and long-term pressures can be conceptualized as resilience [14]. The resilience approach is used because it provides a more comprehensive conceptual framework than adaptation or mitigation alone. This approach encompasses farmers' capacity to maintain short-term stability, adapt to ongoing changes, and transform agricultural systems to ensure long-term sustainability. Therefore, this approach is more appropriate for exploring the dynamics of farmer resilience in the face of complex climate pressures. This study aims to determine what factors can increase the resilience capacity of farmers and, at the same time, the sustainability of rice farming businesses.

Although the island of Java accounts for less than 7% of Indonesia's land area, it contributes approximately 54% of the national rice production (29 million tons) [15]. In West Java, rice production in 2024 has reached 8.5 million tons, marking a 6.84% decrease compared to the previous year [16]. West Java is also recorded as the most vulnerable province in Indonesia to natural disasters such as floods, droughts, and landslides. These vulnerabilities are exacerbated by the impacts of climate change, placing the province 24th globally and first in Indonesia in terms of agricultural sector loss risk [17]. The province experiences a 9.02% decline in rice production for every 1 °C increase in average temperature [18]. Rice production patterns in West Java vary between intensive systems characterized by high planting intensity and heavy chemical inputs and semi-intensive systems involving reduced chemical fertilizer usage and gradual adoption of organic farming. Karawang Regency represents the intensive production model typical of peri-urban areas, while Subang Regency is known for its semi-intensive production in rural areas [19]. The severe climate change pressures in West Java necessitate efforts to enhance the resilience of rice farmers so they can adapt and transform their livelihoods. This strategy requires long-term interventions based on changes in farmers' knowledge, skills, and attitudes. Agricultural extension is critical in strengthening resilience by improving access to technology, markets, and information [20]. Resilience is also closely linked to the concept of sustainable livelihood, which emphasizes how the capacities, assets, and activities of communities, as well as structural transformations, contribute to increased income, improved well-being, and enhanced food security [21].

Previous studies have found that agricultural extension services influence farmers' resilience to climate change, as demonstrated by Knook et al. [22]. However, their study focused on participatory extension methods and was conducted qualitatively, with limited data coverage. Amanah and Kartika [23] also examined the impact of communication and extension services on public knowledge regarding climate change, but their study did not address farmers' resilience. Research on farmer resilience and vulnerability to climate change in Indonesia has generally focused on drought-prone regions in the eastern part of the country [24,25], urban areas [19], or indigenous communities [26]. Studies on rice farmers in Java have mostly been limited to vulnerability assessments in single areas with uniform agricultural typologies [27–29]. There has been no research that discusses the influence of extension and livelihood capital on rice farmers in food barn areas with intensive farming typology in suburban areas and farmers who carry out semi-intensive farming in rural areas, even though both typologies are dominant in Indonesia and Asia.

Studies that integrate the concepts of agricultural extension and livelihood capitals to examine the climate resilience of rice farmers remain scarce. This research addresses that gap. Specifically, it fills two key gaps in the existing literature. First, it explores the combined influence of agricultural extension services and livelihood capitals on farmers' climate resilience in major food-producing regions. Second, this study investigates farmer resilience in food barns with two different farming typologies: intensive and semi-intensive. Both agricultural typologies are widely practised in rice-producing countries in Asia. The selection of two agricultural typologies, intensive and semi-intensive, aims to reflect the diversity of rice farming systems. These differences influence farmers' responses to climate risks, shaping their resilience capacity. This aligns with resilience theory, which states that more flexible, diverse, and adaptive systems tend to be more resilient to external pressures. Understanding this will support the right policy to build farmer resilience to climate change in rice-producing regions globally. Based on the background and problem formulation described above, this study examines the influence of agricultural extension services and livelihood capitals on farmers' climate resilience and the sustainability of their farming practices in Indonesia's major rice-producing regions.

Materials and Methods

Study Area

This study was conducted in two regencies in West Java Province: Karawang Regency, representing intensive agricultural areas, and Subang Regency, representing semi-intensive agricultural areas (Figure 1). The research sites in Karawang included Cilamaya Wetan and Cilamaya Kulon Sub-districts, while in Subang, the sites were Pabuaran and Kalijati Sub-districts. The locations were purposively selected based on agricultural typologies and levels of climate risk, considering that West Java is a national rice production hub with the highest climate vulnerability in the agricultural sector [17,30]. The Indonesian government designated Karawang and Subang as climate resilience super-priority zones for the agricultural sector [30]. Data collection was conducted over a period of five months, from September 2024 to January 2025. The questionnaire trial was conducted in Pamanukan District, Subang Regency, using 30 respondents. Pamanukan District was chosen because it is a rice-producing area with similar characteristics to the research location. The research was conducted after approval from the Ethical Committee on Social Studies and Humanities, National Research and Innovation Agency, Indonesia, with the number of ethical clearance approval: 759/KE.01/SK/09/2024. Additionally, participants provided informed consent to participate in this study.

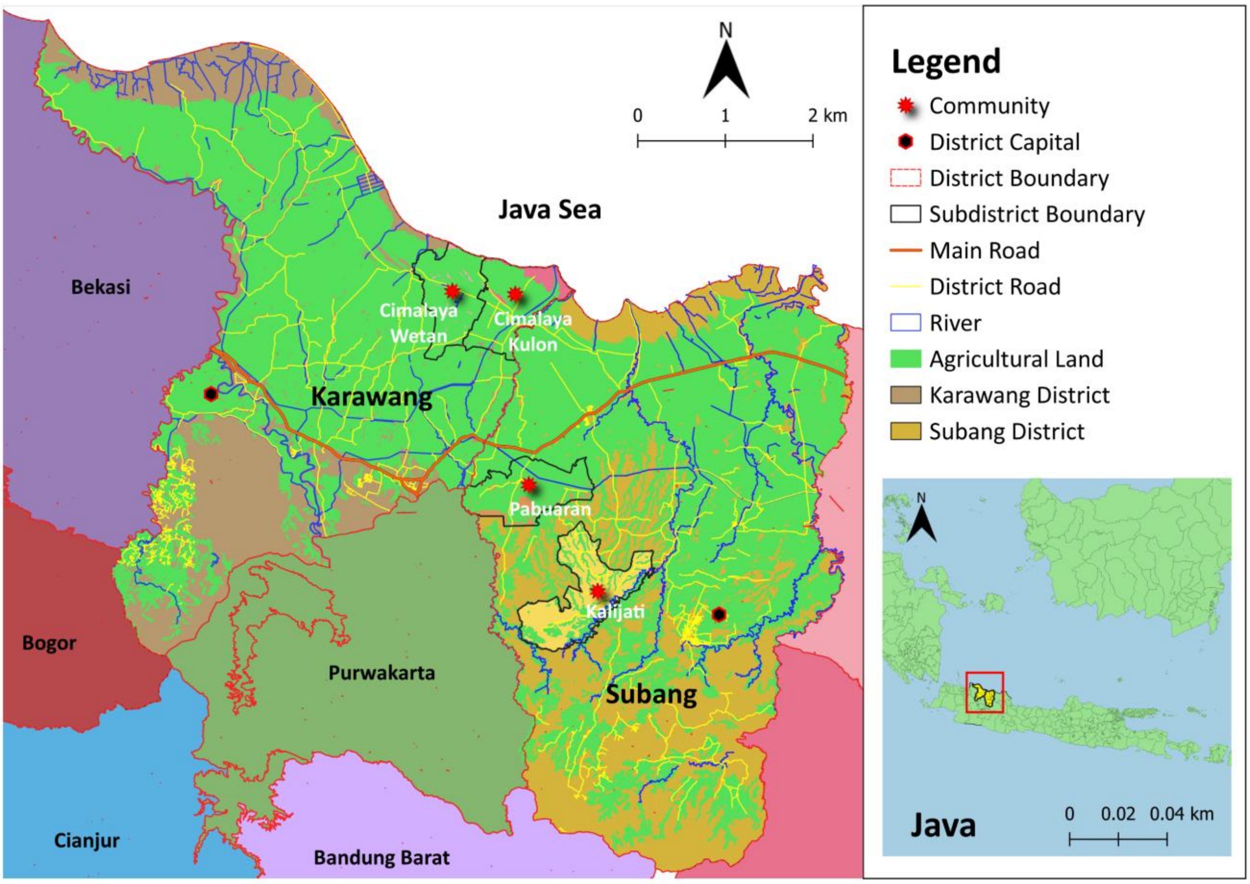

Figure 1. Overview of the study area.

Data Collection Methods

This study employed a survey methodology designed to capture a broad range of variables across a substantial number of respondents. The survey's primary objective was to generate a representative population characterisation by systematically collecting individual-level data through structured interviews. In principle, the range of variables gathered through the survey is extensive, encompassing fundamental attributes, respondents' attitudes and perceptions, social and environmental factors, behavioural patterns, and demographic characteristics of the population under study [31].

The population of this study consists of all members of rice farmer groups actively managing their farming operations. The selection of research locations was carried out purposively, taking into consideration that these farmers are located in eight villages affected by flooding in 2023 within Cilamaya Wetan and Cilamaya Kulon Sub-districts of Karawang Regency, as well as all rice farmer groups in four villages in Subang Regency, specifically in Pabuaran and Kalijati Sub-districts, where some farmers practice semi-intensive rice farming or have begun experimenting with organic rice cultivation. The chosen farmers were also small-scale farmers, with a maximum land area of less than 2 hectares. The total population includes 106 farmer groups, comprising 5,083 individual farmers [32]. The sample size for this study was determined using the Slovin formula [33].

$$n = \frac{N}{1 + Ne^2} = \frac{5{,}083}{1 + 5{,}083\ x\ 0.05^2} = 371 \quad (1)$$

where $\boldsymbol{n}$ represented the study's sample size, $\boldsymbol{N}$ denoted the total number of rice farming households in the study location, and $\boldsymbol{e}$ was a 5% margin of error. The sample size for each district is detailed in Table 1. The questionnaire was initially developed and pilot-tested on 30 rice-farming households in Pamanukan, Subang, to minimize ambiguity, drawing upon insights from relevant literature. Pamanukan was selected for the pre-test due to its significance as a central rice-producing area in West Java. Based on the pilot results, several modifications, such as refining question phrasing and clarifying instructions, were made to improve the overall clarity and comprehensibility of the instrument.

Table 1. Sample size by district.

Districts	Sub-districts	Villages	Population	Proportionate sampling	Actual sampling
Karawang	Cilamaya Wetan	Cilamaya	211	(211/5,083) × 371	16
		Rawa Gempol Kulon	210	(210/5,083) × 371	16
		Muara	613	(613/5,083) × 371	45
		Muara Baru	380	(380/5,083) × 371	27
	Cilamaya Kulon	Sumur Gede	231	(231/5,083) × 371	17
		Pasir Jaya	223	(223/5,083) × 371	16
		Suka Jaya	294	(294/5,083) × 371	21
		Mukti Jaya	219	(219/5,083) × 371	16
Sub total			2,381		174
Subang	Kalijati	Tanggulun Timur	612	(612/5,083) × 371	45
		Tanggulun Barat	588	(588/5,083) × 371	43
	Pabuaran	Pabuaran	936	(936/5,083) × 371	68
		Pringkasap	566	(566/5,083) × 371	41
Sub total			2,702		197
Total			5,083		371

Data Analysis

The measurement model in this study consists of six endogenous latent variables and two exogenous latent variables. These variables include: human capital (X1), agricultural extension implementation (X2), natural capital (X3), physical capital (X4), social capital (X5), financial capital (X6), resilience capacity (Y1), and farm sustainability level (Y2) (Figure 2). The study uses a modified Likert-type ordinal scale, which measures responses based on attitudes, perceptions, and other evaluative statements along a ranked continuum. The scale ranges from one (1), indicating very weak; two (2), indicating weak; three (3), indicating strong, to four (4), indicating very strong. Previous studies [31,34] have used similar coding. Employing ordinal measurement scales, such as the Likert Scale, is recommended as a standardized approach to generate comparable metrics and maintain the assumption of equal intervals between scale points [35].

The data were analyzed using Structural Equation Modelling (SEM) with the assistance of Partial Least Squares software (SmartPLS) version 4.0. The SEM-PLS method was chosen because of its ability to handle complex conceptualisation models with many latent constructs and indicators, and the data's ordinal and non-normal nature. This method also allows for exploring mediating relationships between resilience capacity and farm business sustainability. This approach is relevant for an applied and exploratory study such as this, with the primary goal of predicting and understanding the contribution of each construct to farmers' resilience capacity and farm sustainability.

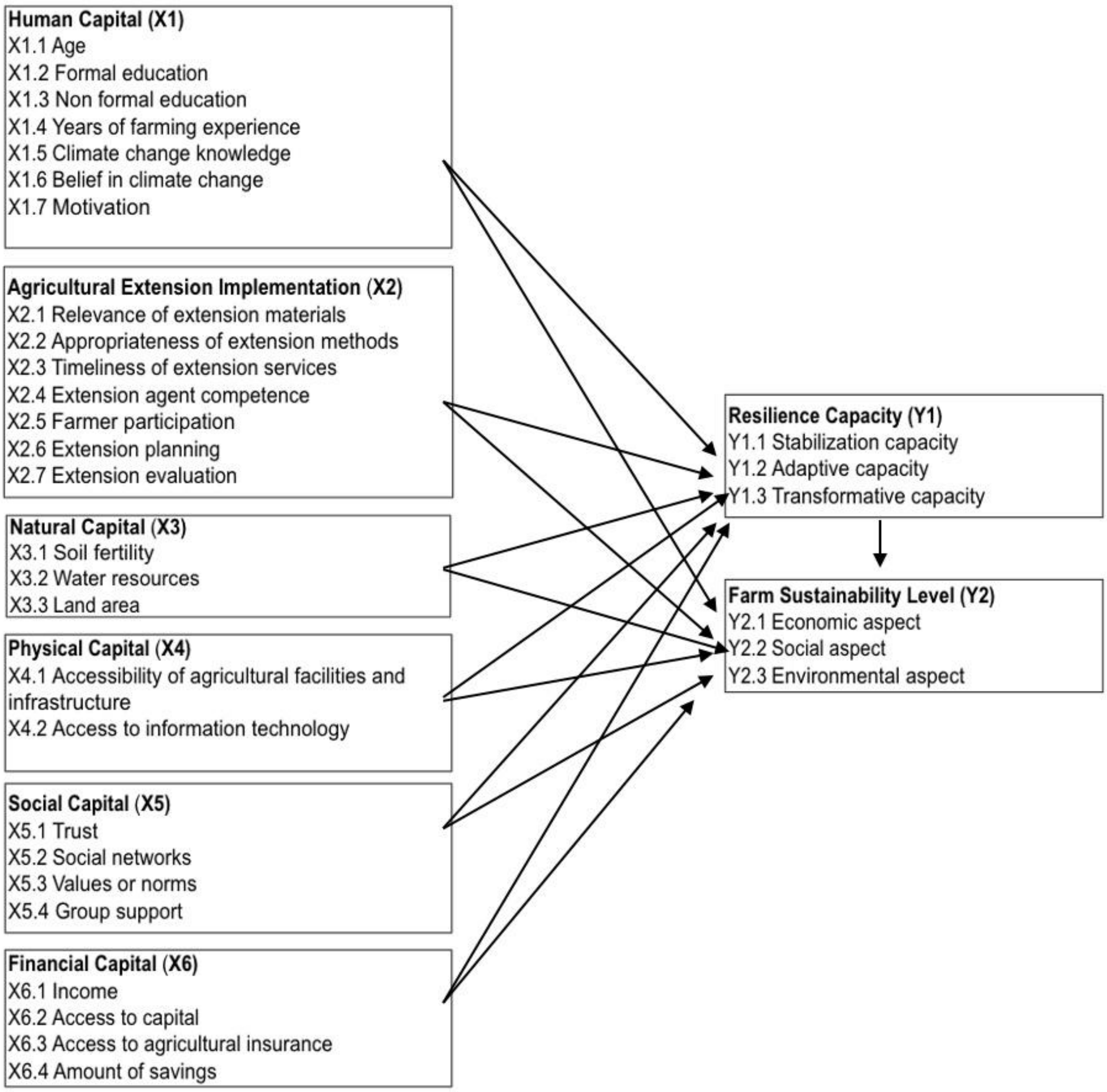

Figure 2. Operational framework of the study.

The evaluation of the PLS model involves assessing both the outer model (measurement model) and the inner model (structural model). The outer model represents the relationships between observed indicators and their corresponding latent constructs. The latent variables and their corresponding research indicators are presented in Table 2. The path analysis model on the inner model is expressed in Equations 2 and 3.

$$Y_1 = \gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \gamma_4 X_4 + \gamma_5 X_5 + \gamma_6 X_6 + e_1 \quad (2)$$

$$Y_2 = \beta_1 Y_1 + \gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \gamma_4 X_4 + \gamma_5 X_5 + \gamma_6 X_6 + e_2 \quad (3)$$

Description :

Y : Endogenous latent variables

X : Exogenous latent variable

β : Path coefficient of endogenous variables

γ : Vector of path coefficients of exogenous to endogenous variables

Table 2. Research variables and indicators.

No	Research variables	Definition	Indicators
1	X1 Human capitals	Conditions or characteristics within an individual that relate to personal aspects, including age, formal education, non-formal education, years of farming experience, knowledge, beliefs, and motivation.	X1.1 Age X1.2 Formal education X1.3 Non-formal education X1.4 Years of farming experience X1.5 Climate change knowledge X1.6 Belief in climate change X1.7 Motivation
2	X2 Agricultural extension implementation	All actions and systems are required to carry out activities to assist and enhance farmers' knowledge and change their behaviour to improve their resilience capacity and increase the efficiency of rice farming. This is assessed through the relevance of extension materials, appropriateness of methods, timeliness of extension services, the competence of extension agents, farmer participation, extension planning, and evaluation of extension programs.	X2.1 Relevance of extension materials X2.2 Appropriateness of extension methods X2.3 Timeliness of extension services X2.4 Extension agent competence X2.5 Farmer participation X2.6 Extension planning X2.7 Extension evaluation
3	X3 Natural capital	Specific characteristics or distinctive features of how farmers organize and manage natural resources to ensure efficiency and consistency, improve their well-being and enhance their standard of living.	X3.1 Soil fertility X3.2 Water resources X3.3 Land area
4	X4 Physical capital	The availability and accessibility of facilities and infrastructure that support farmers' livelihoods in rice farming, encompassing the presence of agricultural and non-agricultural facilities and infrastructure, as well as the ease with which farmers can access these resources.	X4.1 Accessibility of agricultural facilities and infrastructure X4.2 Access to information technology
5	X5 Social capital	Assets possessed by farmers and their communities in the form of social networks, shared values, and trust that facilitate coordination and cooperation for mutual benefit.	X5.1 Trust X5.2 Social networks X5.3 Values or norms X5.4 Group support
6	X6 Financial capital	Financial resources that are available to farmers, including agricultural income, access to capital, access to agricultural insurance, and the amount of savings owned by the farmers.	X6.1 Income X6.2 Access to capital X6.3 Access to agricultural insurance X6.4 Amount savings
7	Y1 Resilience capacity	The level of farmers' ability to cope with pressures in their farming activities is measured through three capacities: stabilization capacity, adaptive capacity, and transformative capacity.	Y1.1 Stabilization capacity Y1.2 Adaptive capacity Y1.3 Transformative capacity
8	Y2 Farm sustainability level	The extent to which farming practices continuously progress toward improvement, as reflected in the levels of economic, social, and environmental sustainability.	Y2.1 Economic aspect Y2.2 Social aspect Y2.3 Environmental aspect

The outer loading assessment for the 27 indicators in this study revealed that 25 indicators satisfied the criteria for convergent validity, exhibiting loading values above 0.60 and statistically significant p-values ($p < 0.05$) (Figure 3). Outer loadings reflect the strength of the relationship between each observed indicator and its corresponding latent construct. The discriminant validity test examined the values of Average Variance

Extracted (AVE) and composite reliability. The results for all variables indicate that AVE values exceed 0.5 and Composite Reliability values exceed 0.7. This indicates that all constructs predict their associated indicators better than those in other blocks, confirming that the research instrument meets the criteria for discriminant validity. In this study, two indicators were removed because they did not meet the composite reliability threshold of > 0.6. This refers to the criteria that if the composite reliability value is less than 0.6, then the indicator is removed [36]. The excluded indicators were X1.1 (age) and X2.3 (timeliness of extension services), resulting in the inner model analysis being conducted using the remaining 25 indicators.

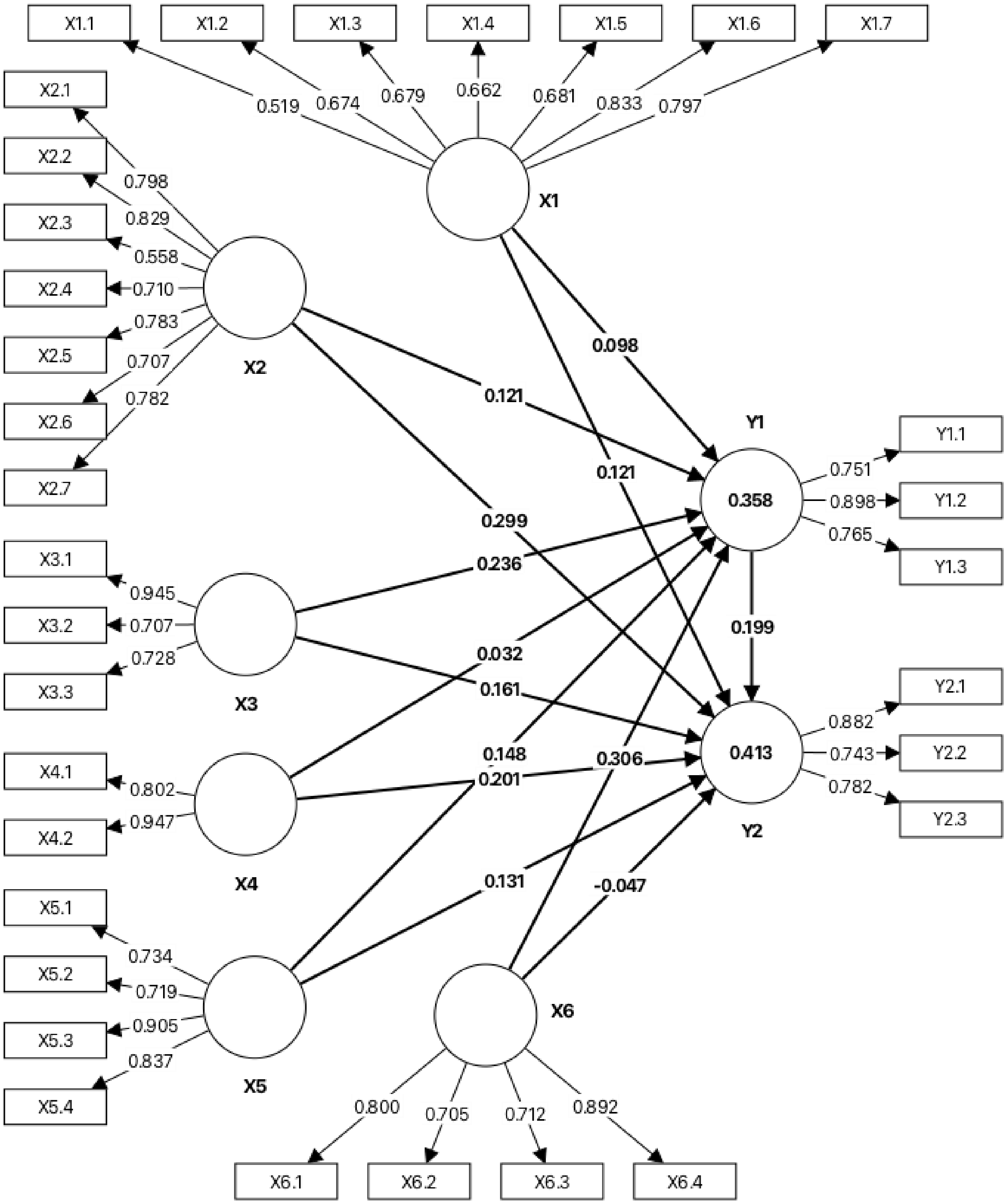

Figure 3. Outer loading test results.

Results

Characteristics of Respondents

Respondents' characteristics encompassed several dimensions. By gender, respondents are male (95.98% in Karawang, 76.65% in Subang) and female (4.02% in Karawang, 23.35% in Subang). In terms of age, respondents were distributed as follows: 21–37 years old (15.52% in Karawang, 8.63% in Subang), 38–54 years old (48.85% in Karawang, 39.59% in Subang), 55–71 years old (33.33% in Karawang, 45.69% in Subang), and 72–86 years old (2.30% in Karawang, 6.09% in Subang). In terms of formal education, respondents had the following educational backgrounds: elementary school (36.78% in Karawang, 58.88% in Subang), junior high school (24.14% in Karawang, 17.77% in Subang), senior high school (36.78% in Karawang, 21.32% in Subang), and a university degree (2.30% in Karawang, 2.03% in Subang). In terms of non-formal education, as measured by the number of training programs attended in the past two years, the results show that respondents fell into the following categories: very low (85.63% in Karawang, 73.10% in Subang) and low (14.37% in Karawang, 26.90% in Subang). In terms of farming experience, the results show that respondents had the following number of years of farming: 5–16 years (54.02% in Karawang, 36.04% in Subang), 17–28 years (28.16% in Karawang, 18.78% in Subang), 29–40 years (16.67% in Karawang, 42.64% in Subang), and 41–50 years (1.15% in Karawang, 2.54% in Subang).

The Influence of Agricultural Extension Services and Livelihood Capitals

Human Capitals

The human capital construct of rice farmers is operationalized through six indicators, including formal and non-formal education, farming experience, knowledge and belief regarding climate change, and motivation. The outer model evaluation results for these indicators are summarized in Figure 3. Based on Figure 3, the outer loading values of the indicators are as follows: formal education (0.674), non-formal education (0.679), years of farming experience (0.662), climate change knowledge (0.681), belief in climate change (0.833), and motivation (0.797). These results indicate that all six indicators represent the latent human capital variable. All indicators positively contribute to the measurement of the human capital construct. Among them, belief in climate change is the most dominant indicator reflecting the latent variable of human capital.

The human capital of rice farmers in Karawang and Subang reflects diverse conditions. Most farmers have only completed primary education (48.52%) and demonstrated low participation in training programs, primarily due to limited access to such opportunities. Nevertheless, farmers in both regions exhibit a high level of awareness regarding climate change in their areas and its adverse impacts on their farming activities. This awareness is accompanied by a strong motivation to continue rice farming. These findings suggest that despite limitations in formal education, farmers possess substantial awareness, understanding, and motivation to adapt. This strength represents a critical asset for developing participatory extension programs, which can accelerate adaptive behavioral transformation and strengthen farmers' resilience to climate-related pressures more effectively. The results of the inner model analysis (Table 3 and Figure 4) indicate that human capital has a significant influence on both resilience capacity ($\beta = 0.103$, $p = 0.022$) and farm sustainability levels ($\beta = 0.119$, $p = 0.008$).

Table 3. Results of inner model analysis.

Relation	Coefficient path	p-Values	Description
Human capitals → Resilience capacity	0.103	0.022*	Significant
Human capitals → Farm sustainability level	0.119	0.008*	Significant
Agricultural extension implementation → Resilience capacity	0.126	0.013*	Significant
Agricultural extension implementation → Farm sustainability level	0.311	0.000*	Significant
Natural capital → Resilience capacity	0.235	0.000*	Significant
Natural capital → Farm sustainability level	0.159	0.004*	Significant
Physical capital → Resilience capacity	0.031	0.568	Not significant
Physical capital → Farm sustainability level	0.196	0.000*	Significant
Social capital → Resilience capacity	0.145	0.005*	Significant
Social capital → Farm sustainability level	0.127	0.022*	Significant
Financial capital → Resilience capacity	0.305	0.000*	Significant
Financial capital → Farm sustainability level	–0.047	0.416	Not significant
Resilience capacity → Farm sustainability level	0.196	0.000*	Significant

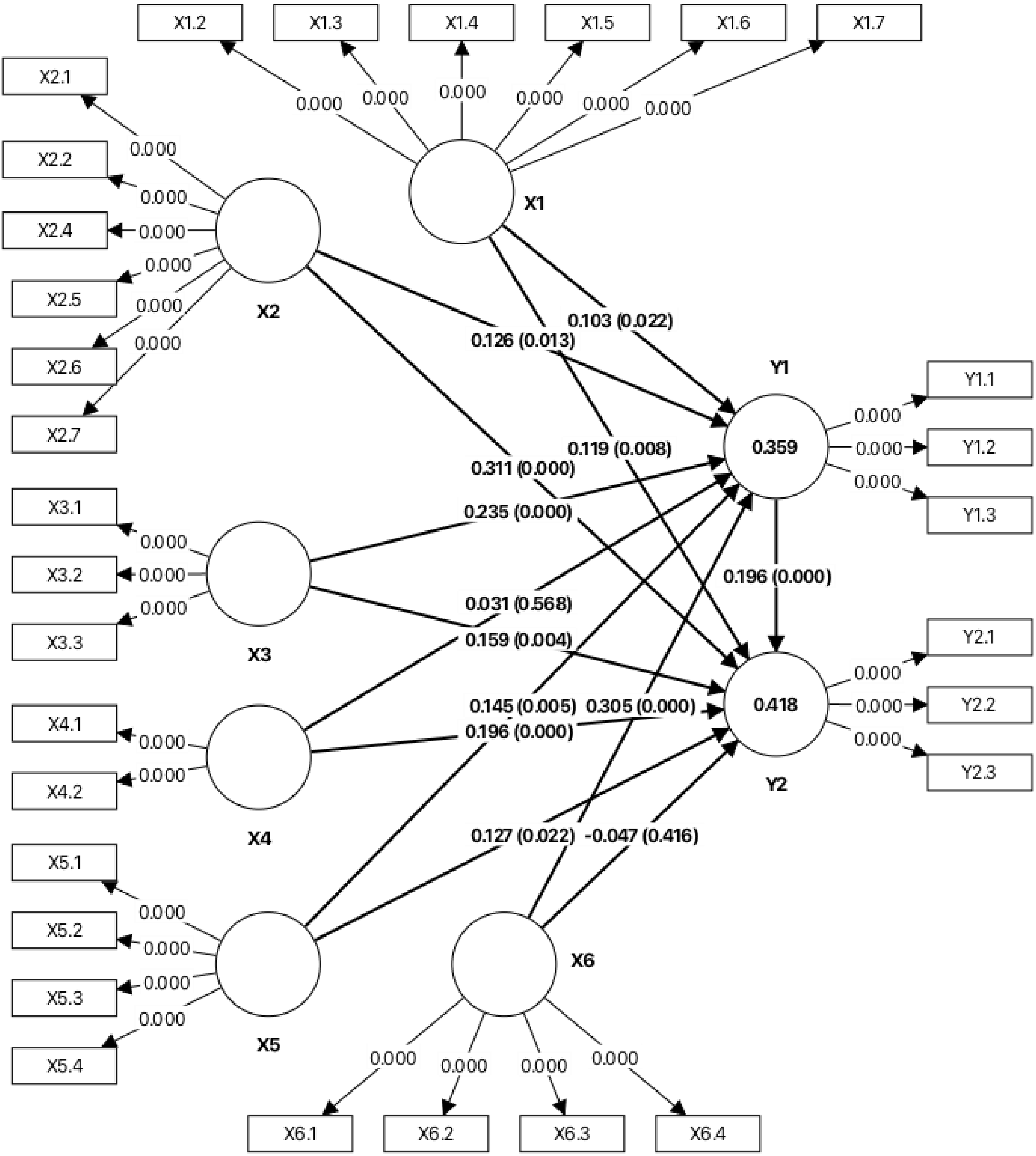

Figure 4. Inner model analysis results.

Agricultural Extension Implementation

The agricultural extension implementation construct is operationalized through six indicators, including the relevance of extension materials, the appropriateness of extension methods, the competence of extension agents, farmer participation, extension planning, and extension evaluation. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of agricultural extension implementation is reflected in all of its indicators. All indicators positively contribute to measuring the agricultural extension implementation construct. The most dominant indicator is the appropriateness of extension methods, which best represents the agricultural extension implementation variable. The results of the inner model analysis (Table 3) indicate that the implementation of agricultural extension has a significant impact on resilience capacity ($\beta = 0.126$, $p = 0.013$) and farm sustainability levels ($\beta = 0.311$, $p < 0.000$).

Agricultural extension services in Karawang and Subang still rely heavily on government-led initiatives. Although some extension activities are conducted by the private sector, particularly by fertilizer and pesticide companies, as well as farmer-to-farmer or self-organized efforts, these remain limited in scale and scope. The capacity of government extension agents is also constrained, particularly in terms of human resources. Each sub-district is typically served by only 5 to 7 extension officers, requiring each officer to support 15 to 17 farmer groups, translating to approximately 800 to 900 rice farmers per extension agent. In addition, these government officers face significant bureaucratic and administrative burdens, with much of their time consumed by the technical and procedural aspects of government programs. Nevertheless, their presence remains crucial in the field, particularly in facilitating farmers' access to agricultural inputs, especially subsidized fertilizers.

Natural Capital

Natural capital construct is operationalized through three indicators, including soil fertility, water resources, and land area. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of natural capital is reflected in all its indicators. All indicators positively contribute to the measurement of natural capital construction. The most dominant indicator is soil fertility, which best represents the natural capital variable.

The natural capital of rice farmers in Karawang and Subang is notably limited, as indicated by low soil fertility, difficult access to water resources, and very small landholdings, where all farmers cultivate less than two hectares, with the majority farming on plots smaller than one hectare. These three indicators reflect a weak ecological foundation underpinning the rice farming system, which significantly constrains farmers' adaptive capacity to climate change. Such limitations not only hinder productivity but also reduce the ability of farmers to invest in sustainable agricultural practices. Therefore, efforts to enhance farmers' climate resilience must be accompanied by improvements in the structure of natural capital through programs aimed at restoring soil fertility, expanding equitable access to irrigation infrastructure, and implementing land governance policies that promote farm consolidation and land-use efficiency. The results of the inner model analysis (Table 3 and Figure 4) show that natural capital exhibits significant effects on resilience capacity ($\beta = 0.235$, $p < 0.000$) and farm sustainability levels ($\beta = 0.159$, $p < 0.004$).

Physical Capital

Physical capital construct is operationalized through two indicators, including accessibility of agricultural facilities and infrastructure, and access to information technology. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of physical capital is reflected in all its indicators. All indicators positively contribute to the measurement of physical capital construction. The most dominant indicator is access to information technology, which best represents the physical capital variable.

One of the key physical infrastructures available to farmers is the irrigation system. Karawang and Subang are served by three major irrigation canals, Tarum Utara, Tarum Tengah, and Tarum Barat, which supply water to rice fields and fishponds and contribute to electricity generation. However, some of the irrigation facilities in the study areas have begun to deteriorate, exacerbating conditions during the dry season, when many rice fields experience drought. In contrast, post-harvest facilities such as rice mills managed by local communities are relatively well-established and easily accessible to farmers. Beyond reliable irrigation, another critical physical asset farmers need is water pumps, which help channel water to the fields during dry periods. The results of the inner model analysis (Table 3 and Figure 4) show that physical capital does not significantly influence resilience capacity ($\beta = 0.031$, $p = 0.568$) but significantly affects farm sustainability levels ($\beta = 0.196$, $p < 0.000$).

Social Capital

The social capital construct is operationalized through four indicators, including trust, social networks, values or norms, and group support. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of social capital is reflected in all its indicators. All indicators positively contribute to the measurement of social capital construction. The most dominant indicator is values or norms, which best represent the social capital variable.

Farmers' social capital is categorized as high, as reflected in the strong networks of trust, solidarity, and cooperation among farmers in agricultural and broader community activities. Farmers in Karawang and Subang actively participate in farmer groups, informal savings groups (arisan), religious events, and mutual aid (gotong royong), all of which serve as vital social support mechanisms in managing climate-related risks and uncertainties in agricultural yields. This social capital also enhances farmers' collective capacity to access agricultural information, technologies, and external support such as subsidies, crop insurance, and extension programs. Furthermore, trusted informal leaders within the community facilitate collective decision-making and joint management of shared resources. These findings indicate that substantial social capital plays a crucial role in strengthening farmers' adaptive resilience to climate change pressures; therefore, it should be integrated into the design of community-based agricultural development interventions. The results of the inner model analysis (Table 3 and Figure 4) show that social capital shows significant positive relationships with both resilience capacity ($\beta = 0.145$, $p = 0.005$) and farm sustainability levels ($\beta = 0.127$, $p = 0.022$).

Financial Capital

Financial capital construct is operationalized through four indicators, including income, access to capital, access to agricultural insurance, and amount of savings. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of financial capital is reflected in all its indicators. All indicators positively contribute to the measurement of financial capital construction. The most dominant indicator is the amount of savings and income, which best represents the financial capital variable.

The average income of farmers in the study area was IDR 3,360,692, which falls into the high-income category based on the income classification used by the Indonesian government. This income includes not only on-farm earnings but also off-farm and non-farm sources. Access to banking institutions is relatively good, with 49% of respondents reporting ease in obtaining loans from formal financial institutions. However, around 51% of farmers remain dependent on informal sources, such as loans from family members and local moneylenders, to support their livelihoods. The results of the inner model analysis (Table 3 and Figure 4) show that financial capital significantly influences resilience capacity ($\beta = 0.305$, $p < 0.000$), but its impact on farm sustainability levels is not significant ($\beta = –0.047$, $p = 0.416$).

Resilience Capacity

The resilience capacity construct is operationalized through three indicators, including stabilization capacity, adaptive capacity, and transformative capacity. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of resilience capacity is reflected in all its indicators. All indicators positively contribute to the measurement of resilience capacity construction. The most dominant indicator is adaptive capacity, which best represents the resilience capacity variable.

Figure 5 shows the level of rice farmers' resilience capacity in Karawang and Subang District. An analysis of the resilience capacities of rice farmers in Karawang and Subang reveals that stabilization capacity is the highest (50.3), followed by adaptive capacity (35.89), with transformative capacity being the lowest (24). This pattern suggests that farmers can maintain their farming practices under short-term climatic stress but face limitations in adjusting their strategies or initiating the structural changes necessary for long-term resilience. The low adaptive and transformative capacities reflect limited access to information, technology, and institutional support. Without strengthening these dimensions, farmer resilience will remain reactive and unsustainable. Therefore, policy interventions should focus on enhancing the effectiveness of agricultural extension services, providing climate-adaptive technologies, and empowering local institutions to support a more resilient and transformative agricultural system. The results of the inner model analysis (Table 3 and Figure 4) indicate that resilience capacity has a significant influence on the level of farm sustainability ($\beta = 0.196$, $p < 0.000$).

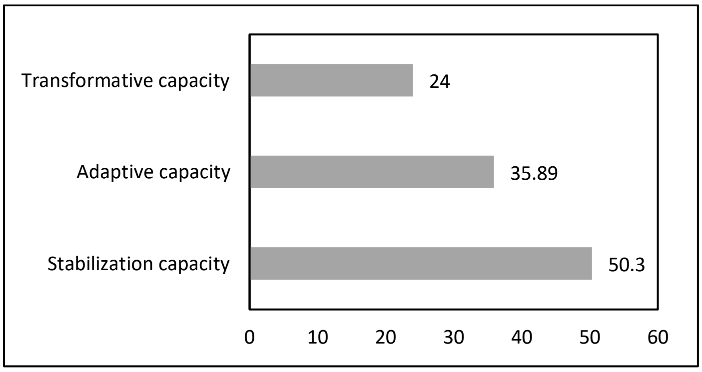

Figure 5. The level of rice farmers' resilience capacity in Karawang and Subang District.

Farm Sustainability Level

The farm sustainability construct is operationalized through three indicators: the economic aspect, the social aspect, and the environmental aspect. The outer model evaluation results for these indicators are summarized in Figure 3. Figure 3 shows that the latent variable of farm sustainability level is reflected in all its indicators. All indicators positively contribute to the measurement of the farm sustainability level of construction. The most dominant indicator is the economic aspect, which best represents the level of farm sustainability.

The sustainability assessment of rice farming in Karawang and Subang reveals a critical imbalance across three key economic, social, and environmental dimensions (Figure 6). The data indicate that most farms fall into the moderate sustainability category, particularly in the social (82.75%) and economic (42.33%) domains, while the environmental aspect is significantly underperforming, with 60.11% of farms categorized as having low sustainability. High or very high sustainability remains virtually absent in all dimensions.

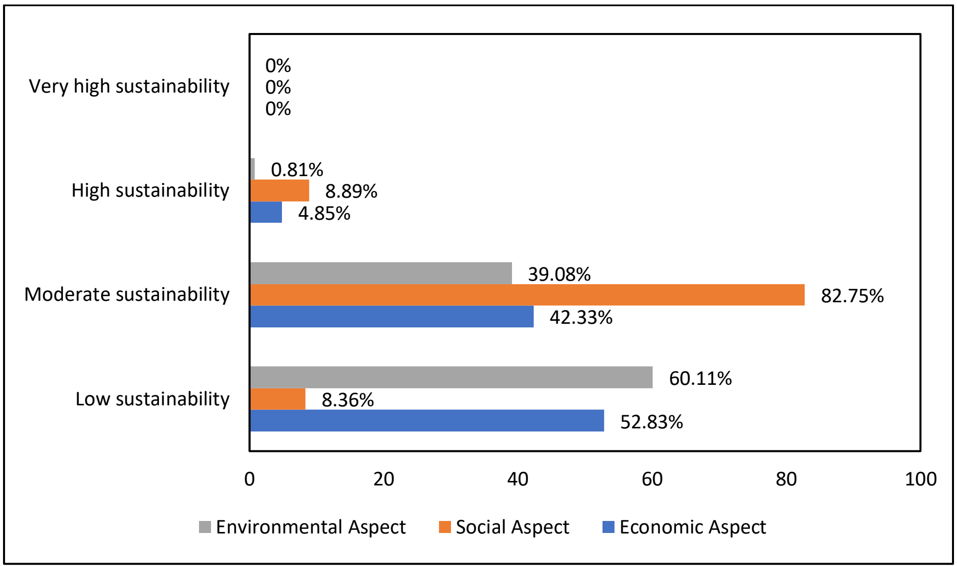

Figure 6. The level of farm sustainability in Karawang and Subang District.

Model Quality Indicators

The structural model quality in this study was evaluated using R-squared (R^2), adjusted R-squared, Q-squared (Q^2), the goodness of fit index (GoF), and the standardized root mean square residual (SRMR). The results of the model quality assessment are presented in Table 4.

Table 4. Results of the structural model quality analysis.

Model quality indicators	Criteria	Results	Description
R Square	Category: 0.33–0.66 (Moderate)	0.625	Moderate
R Square adjusted	Category: 0.33–0.66 (Moderate)	0.618	Moderate
Q Square	0 = Low predictive relevance, 0.25 = Moderate predictive relevance, 0.50 = High predictive relevance.	0.310	Moderate
Index goodness of fit (GoF)	0.10 = Small (low) GoF, 0.25 = Medium GoF, 0.36 = Large (high) GoF.	0.491	High
Standardized root mean square residual (SRMR)	≤ 0.08 (the model demonstrates a good fit), > 0.08 (the model demonstrates a poor fit).	0.06	Good
Varian Inflation Factor (VIF)	< 5 = There is no indication of multicollinearity.	1.35–2.88	There is no multicollinearity

The R^2 value was 0.625, and the adjusted R^2 was 0.618, indicating that 62.5% of the variance in resilience capacity and farm sustainability can be explained by the model, with a slight adjustment to 61.8% after accounting for the number of independent variables and the sample size. The Q^2 value was 0.310, suggesting the model can explain 31% of the variance in unobserved data. This value reflects the model's relatively good predictive relevance. The GoF index indicates how well the measurement and structural models fit the overall data, thereby assisting in assessing the model's suitability. The results show a GoF value of 0.491, which falls into the high category, suggesting that the model provides an excellent fit. The SRMR value was 0.06, below the recommended threshold of 0.08, indicating that the model demonstrates a good fit. Multicollinearity testing used the Variance Inflation Factor (VIF) on all exogenous constructs in the structural model. The analysis showed that all VIF values ranged from 1.35 to 2.88, below the threshold value of 5. This indicates no significant multicollinearity problem and that each exogenous variable contributes independently to the endogenous variables.

Importance-Performance Map Analysis (IPMA) For Resilience Capacity

The results of the Importance-Performance Map Analysis (IPMA) (Figure 7) indicate that financial capital (X6) holds the highest level of importance (total effects = 0.28) but exhibits the lowest performance score (20). This suggests that although financial capital is critical in strengthening farmers' resilience capacity, its implementation remains inadequate and should be prioritized in future policy interventions. Natural capital (X3) ranks second in importance (0.24). However, its performance score remains below average (38), emphasizing the need to enhance access to and management of natural resources that support farmers' adaptive capacity.

Agricultural extension implementation (X2) demonstrates an average performance score (40) with a moderate level of importance (0.14), positioning it as a relatively important factor that has begun to be optimized, yet still requires improvement to increase its overall impact. In contrast, human capital (X1) shows a similar level of importance (0.13) but a lower performance score (35), indicating a need to further strengthen individual farmer capacity and education. On the other hand, social capital (X5) and physical capital (X4) achieve the highest performance scores (55 and 53, respectively), yet their importance scores are relatively low (0.13 and 0.08). This implies that while these two dimensions are well implemented in practice, their overall contribution to resilience is less significant than that of others. Therefore, resource allocation and program focus should be adjusted to strengthen dimensions with high importance but low performance, particularly financial capital, natural capital, and the effectiveness of agricultural extension services.

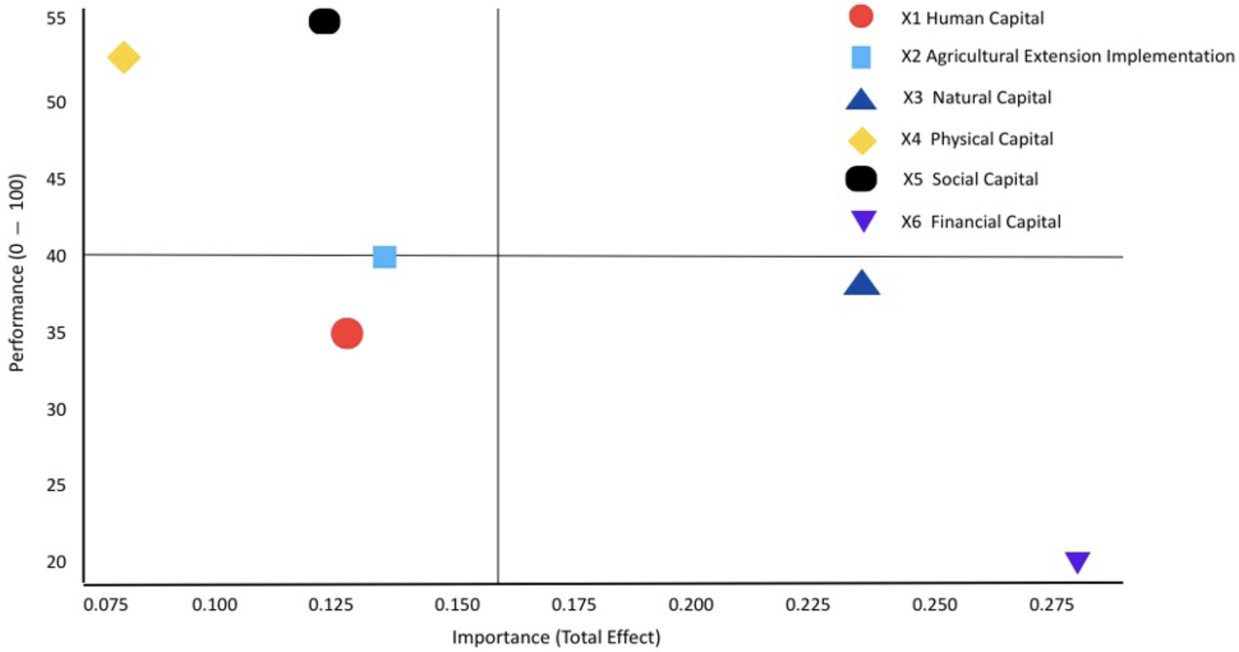

Figure 7. IPMA analysis results.

Discussion

The results of the inner model analysis show that five out of six independent variables tested have a positive and significant influence on farmers' resilience capacity. These variables are human capital, agricultural extension implementation, natural, social, and financial capital. The results of the inner model analysis also show that five out of six independent variables tested have a positive and significant influence on the farm sustainability level. These variables are human capital, agricultural extension implementation, natural, social, and physical capital. The positive and significant effect of human capital on farmers' resilience and farm sustainability level indicates that improvements in farmers' knowledge, skills, and education can strengthen their ability to respond to climate pressures while enhancing productivity and the sustainability of agricultural systems. This finding is consistent with Abid et al. [37], who emphasize the importance of farmers' capacity to make adaptive decisions. Numerous previous studies have confirmed that their social and economic conditions strongly influence individual perceptions of climate change and corresponding adaptation strategies. For example, Chimi et al. [38] found that education significantly influences farmers' perceptions of climate change. Likewise, farmers' beliefs about climate change shape their perceptions and influence their adaptive actions in response to climate-related challenges [39].

Agricultural extension implementation shows a positive and significant effect on both resilience capacity and farm sustainability level, with the highest path coefficient among all the variables. This indicates that the effectiveness of extension services is crucial in promoting adaptive and long-term-oriented agricultural practices. This finding is consistent with several previous studies that emphasize the critical role of agricultural extension in enhancing farmers' resilience. Access to extension services has been shown to influence the level of livelihood vulnerability among farmers significantly [40]. Antwi-Agyei and Stringer [41] highlighted the crucial role of agricultural extension in supporting farmers to cope with the challenges of climate change. Baffour-Ata et al. [42] also indicates that agricultural extension contributes significantly to increasing income and reducing food insecurity among smallholder farmers. However, as is the case in many developing countries, agricultural extension in Indonesia continues to face several challenges, including limited funding, regulatory uncertainty, inadequate human resource capacity among extension workers, and weak inter-agency coordination in extension delivery.

These issues have resulted in the low effectiveness of extension services in reaching smallholder farmers, limited dissemination of science- and technology-based information, and slow adoption of adaptive innovations at the field level. These challenges have become even more critical in the context of climate change, which demands that agricultural extension systems be more adaptive, responsive, and context-specific. The study by Birner et al. [43] emphasizes that the effectiveness of agricultural extension services largely depends on how the system is comprehensively designed. Extension systems must be tailored to local, institutional, and farmer-specific contexts rather than replicating successful practices elsewhere. This perspective is highly relevant in Indonesia, a country characterized by vast geographic, social, and economic diversity. Such diversity calls for a flexible and context-specific extension model to effectively enhance farmers' resilience to climate change.

Natural capital also positively and significantly affects resilience capacity and farm sustainability. This indicates that access to adequate natural resources such as water, fertile soil, and sufficient land is critical for building resilient agricultural systems. The degradation of natural resources directly affects farmers' ability to cope with climate change. This finding is consistent with previous studies, which have shown that the condition and accessibility of natural capital, particularly water, play a crucial role in shaping farmers' resilience to climate pressures and serve as a key pillar of rice farming sustainability in climate-vulnerable regions [44].

Social capital also positively and significantly affects resilience capacity and the farm sustainability level. This finding suggests that social networks, trust, and collaboration among farmers are essential resources for strengthening adaptive and sustainable agricultural systems. Previous studies have also highlighted that social capital is fundamental in building resilience and farm sustainability, particularly by strengthening farmer organizations. Social capital fosters collaboration, information sharing, and collective decision-making that support the continuity of agricultural production amid climate and market pressures [45].

Financial capital makes a substantial contribution to resilience capacity but does not have a significant effect on farm sustainability. This reflects that while the availability of funds or access to financial resources can be key in addressing short-term risks, it is insufficient to ensure long-term sustainability without transforming farming practices. The study by Tanti et al. [46] highlights that financial capital, particularly subsidies and agricultural credit, is crucial for enhancing farmers' adaptive capacity and resilience to climate change. Without adequate financial support, farmers face significant barriers in adopting the innovations needed to maintain productivity and the resilience of their farming systems. A study by Hendrawan et al. [47] also found that the most vulnerable group of farmers was those with extremely low levels of financial capital.

The academic literature generally agrees that access to financial capital enhances smallholder farmers' capacity to withstand shocks, enabling them to purchase emergency inputs, finance replanting after a crop failure, pursue alternative income sources, or adopt adaptive technologies. However, financial capital does not necessarily significantly impact farm sustainability. This may be because increased financial capital can lead to production intensification or land expansion, which, if not properly regulated, may compromise environmental sustainability. A theoretical study by Guthrie [48] suggests that access to credit or pressure to meet income targets can drive farmers to maximize short-term returns (e.g., through excessive use of fertilizers, pesticides, or land clearing) at the expense of soil health and environmental preservation. This condition is called the “debt overhang” problem, where debt burdens lead to short-term decision-making in farm management.

Physical capital shows a contrasting result. Its effect on resilience capacity is not significant, but it significantly influences farm sustainability. This finding suggests that infrastructure and agricultural tools play a greater role in enhancing long-term efficiency and productivity in farming rather than directly supporting immediate responses to climate-related pressures. Several empirical studies examining farmers' resilience to climate change have shown that the impact of physical capital is statistically insignificant. For example, Awazi et al. [49] investigated 350 smallholder farming households in the highlands of Cameroon to assess how different livelihood assets affect climate resilience. The survey results indicated that improvements in physical assets, such as ownership of irrigation infrastructure or other facilities, did not automatically enhance farmers' resilience to climate impacts. Instead, intangible factors such as knowledge (human capital) and networks or institutions (social capital) were found to play a more critical role in strengthening farmers' resilience. A study conducted in the Jianghan Plain, China, examined the adoption of climate-smart agricultural practices among rice farmers and found no significant effect of physical capital on farmers’ climate resilience [50].

Resilience capacity has a significant effect on the level of farm sustainability. This finding confirms that resilience is not only a tool for adaptation but also serves as a foundation for transforming agricultural systems toward greater sustainability. It supports previous research suggesting that resilience-based approaches should be developed within a broader and more systemic agricultural development framework [51,52]. The IPMA results on farmers' resilience capacity reveal that financial capital holds the highest importance but the lowest performance, indicating an urgent need to improve farmers' access to inclusive and adaptive financial services. Natural capital also shows high importance with moderate performance, underscoring the need for sustainable protection and management of natural resources. In contrast, social and physical capital demonstrate high performance but moderate contributions to resilience, suggesting they should be maintained while further optimizing their role in collective adaptation strategies. Agricultural extension implementation and human capital are positioned at moderate levels in both importance and performance, yet still require improvements in quality and coverage to enhance their impact.

Therefore, climate adaptation policies in the agricultural sector should prioritize strengthening farmers' access to finance, improving natural resource governance, and promoting extension models that are responsive to farmers' varying capacities and needs. A resilience-building model that integrates human, social, natural, physical, and financial capital can serve as a foundation for enhancing farmers' resilience to climate change. Adaptive and pluralistic agricultural extension, which integrates diverse knowledge sources and aligns approaches with local contexts, can enhance farmers' resilience. These findings highlight the need to transform extension approaches from linear and standardized models to pluralistic systems grounded in sustainable livelihoods, collaboration, and behaviour change that is context-specific (best fit) and dynamic. Although this research was conducted in two districts in West Java, its conceptual approach and key findings can be transferred to other regions in Indonesia with similar agroecological characteristics and agricultural structures. However, further studies in various local contexts are needed to ensure stronger external validity.

Conclusions

This study concludes that agricultural extension services, alongside livelihood capitals, particularly human, natural, social, and financial, play a critical role in shaping the resilience capacity of rice farmers to climate change in West Java. Based on the findings of this study, it is necessary to develop more adaptive and contextual agricultural extension policies to address changing climate pressures. The government and stakeholders need to develop a pluralistic extension model, involving various actors such as government extension workers, pioneering farmers, non-governmental organisations, and the private sector, with an approach based on local needs and oriented towards increasing farmer resilience. Extension programs also need to integrate climate information services, participatory learning, and strengthen the institutional capacity of farmer groups. Furthermore, expanding access to inclusive financial services is a key priority, such as developing weather-based agricultural insurance and adaptive credit schemes that support climate-friendly innovations.

In terms of natural resources, increasing access to irrigation water, land rehabilitation, and reforming more equitable land governance will be crucial for the success of agricultural businesses amidst climate change. Therefore, future agricultural development strategies need to be integrated, combining interventions across technical, institutional, and socio-ecological aspects to strengthen the resilience of the agricultural system as a whole. The research expands the understanding of resilience capacity theory by emphasising that farmer resilience to climate change is not merely a personal attribute or individual adaptive capacity, but rather the result of complex interactions between farmers' institutional, structural, and livelihood capital factors. This study has limitations. It was conducted in only two districts in West Java and focused on rice farmers, so the results may not be fully generalizable to other commodities or regions. Further research is recommended, including cross-regional comparative studies with different agrarian typologies. Integrating qualitative approaches is also crucial to deepen understanding of the institutional and behavioural aspects of building farmer resilience to climate change.

Author Contributions

RA: Conceptualization, Methodology, Software, Investigation, Writing; **SA:** Conceptualization, Writing - Review & Editing, Supervision; **AF:** Conceptualization, Writing - Review & Editing, Supervision; and **RAK:** Conceptualization, Writing - Review & Editing, Supervision.

Conflicts of Interest

There are no conflicts to declare.

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References

1. Chimi, P.M.; Mala, W.A.; Fobane, J.L.; Abdel, K.N.; Nkoué, B.B.; Nganmeni, L.F.F.; Pokam, E.Y.N.; Minfele, S.P.E.; Matick, J.H.; Tchandjie, F.M.; et al. Factors Affecting Decision-Making to Strengthen Climate Resilience of Smallholder Farms in the Centre Region of Cameroon. *Climate Smart Agriculture* **2024**, *1*, 1–11, doi:10.1016/j.csag.2024.100004.
2. Guo, H.; Wang, R.; Garfin, G.M.; Zhang, A.; Lin, D.; Liang, Q.; Wang, J. Rice Drought Risk Assessment under Climate Change: Based on Physical Vulnerability a Quantitative Assessment Method. *Science of The Total Environment* **2021**, *751*, 1–14, doi:10.1016/j.scitotenv.2020.141481.
3. Government of the Republic of Indonesia. Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050. 2021. Available online: https://unfccc.int/sites/default/files/resource/Indonesia_LTS-LCCR_2021.pdf (accessed on 15 April 2025).
4. Saptutyningsih, E.; Diswandi, D.; Jaung, W. Does Social Capital Matter in Climate Change Adaptation? A Lesson from Agricultural Sector in Yogyakarta, Indonesia. *Land Use Policy* **2020**, *95*, 1–5, doi:10.1016/j.landusepol.2019.104189.
5. The World Bank. *Climate Risk Country Profile: Indonesia*; The World Bank Group: Washington DC, USA, 2021;
6. IPCC (Intergovernmental Panel on Climate Change). Summary for Policymakers. In Climate Change 2022 Impacts, Adaptation and Vulnerability. Available online: https://www.ipcc.ch/report/ar6/wg2/chapter/summary-for-policymakers/ (accessed on 15 April 2025).

7. BPS (Badan Pusat Statistik) Indonesia. Pada 2024, luas panen padi mencapai sekitar 10,05 juta hektare dengan produksi padi sebanyak 53,14 juta ton gabah kering giling (GKG). Available online: https://www.bps.go.id/id/pressrelease/2025/02/03/2414/pada-2024--luas-panen-padi-mencapai-sekitar-10-05-juta-hektare-dengan-produksi-padi-sebanyak-53-14-juta-ton-gabah-kering-giling--gkg--.htm (5 February 2025).
8. BPS (Badan Pusat Statistik) Indonesia. Hasil Pencacahan Lengkap Sensus Pertanian 2023 - Tahap I. Available online: https://www.bps.go.id/id/pressrelease/2023/12/04/2050/hasil-pencacahan-lengkap-sensus-pertanian-2023---tahap-i.html (5 February 2025).
9. de Steenhuijsen Piters, B.; Termeer, E.; Bakker, D.; Fonteijn, H.; Brouwer, H. *Food System Resilience: Towards a Joint Understanding and Implications for Policy*; Wageningen Economic Research: Den Haag, Netherlands, 2021;
10. Shah, K.U.; Dulal, H.B.; Johnson, C.; Baptiste, A. Understanding Livelihood Vulnerability to Climate Change: Applying the Livelihood Vulnerability Index in Trinidad and Tobago. *Geoforum* **2013**, *47*, 125–137, doi:10.1016/j.geoforum.2013.04.004.
11. Puspitasari, D.C.; Aini, M.N.; Satriani, R. Penguatan Resiliensi dan Strategi Penghidupan Masyarakat Rawan Bencana. *Talenta Conference Series: Local Wisdom, Social, and Arts (LWSA)* **2019**, *2*, 1–10, doi:10.32734/lwsa.v2i1.592.
12. Darnhofer, I. Farming Resilience: From Maintaining States towards Shaping Transformative Change Processes. *Sustainability* **2021**, *13*, 1–21, doi:10.3390/su13063387.
13. Amekudzi, A.; Khayesi, M.; Khisty, C.J. Sustainable Development Footprint: A Framework for Assessing Sustainable Development Risks and Opportunities in Time and Space. *International Journal Sustainable Development* **2015**, *18*, 9–21.
14. Meuwissen, M.P.M.; Feindt, P.H.; Spiegel, A.; Termeer, C.J.A.M.; Mathijs, E.; de Mey, Y.; Finger, R.; Balmann, A.; Wauters, E.; Urquhart, J.; et al. A Framework to Assess the Resilience of Farming Systems. *Agriculture System* **2019**, *176*, 1–10, doi:10.1016/j.agsy.2019.102656.
15. BPS (Badan Pusat Statistik) Indonesia. *Luas Panen dan Produksi Padi di Indonesia 2023*; BPS: Jakarta, ID, 2024;
16. BPS (Badan Pusat Statistik) Indonesia. Pada 2024, Produksi Padi Jawa Barat diperkirakan sekitar 8,51 juta ton GKG. 2024. Available online: https://jabar.bps.go.id/id/pressrelease/2024/11/01/1165/pada-2024--produksi-padi-jawa-barat-diperkirakan-sekitar-8-51-juta-ton-gkg.html (accessed on 16 April 2025).
17. XDI. *2023 XDI Gross Domestic Climate Risk Report*; XDI (Cross Dependency Initiative): Australia, 2023; ISBN 9780646890630.
18. Massagony, A.; Ho, T.T.; Shimada, K. Climate Change Impact and Adaptation Policy Effectiveness on Rice Production in Indonesia. *International Journal of Environmental Studies* **2023**, *80*, 1373–1390, doi:10.1080/00207233.2022.2099110.
19. Mulya, S.P.; Hudalah, D. Agricultural Intensity for Sustainable Regional Development: A Case Study in Peri-Urban Areas of Karawang Regency, Indonesia. *Regional Sustainability* **2024**, *5*, 1–18, doi:10.1016/j.regsus.2024.100117.
20. Ozkan, B.; Dube, A.K.; Reed, M.R. Role of agricultural extension in building climate resilience of food security in Ethiopia. In *Food Security and Climate-Smart Food Systems*; Behnassi, M., Baig, M.B., Sraïri, M.T., Alsheikh, A.A., Abu Risheh, A.W.A., Eds.; Springer: Cham, Switzerland, 2022; pp. 219–239, ISBN 978-3-030-92737-0.
21. Obrist, B.; Pfeiffer, C.; Henley, R. Multi-Layered Social Resilience: A New Approach in Mitigation Research. *Progress in Development Studies* **2010**, *10*, 283–293, doi:10.1177/146499340901000402.
22. Knook, J.; Eastwood, C.; Beehre, L.; Mitchelmore, K.; Barker, A. Resilience Building in Agricultural Extension Programmes: Application of a Resilience Framework and Development of a Farmer-Focused Assessment Tool. *Journal of Agricultural Education and Extension* **2023**, *30*, 753–773.
23. Amanah, S.; Kartika, N.W. Communication and Advisory Services to Develop Community Knowledge to Climate Change: Citarum River Basin Context. In Proceedings of the 2nd International Conference on Rural Socio-Economic Transformation: Agrarian, Ecology, Communication and Community Development Perspectives, Bogor, Indonesia, 14–15 September 2021.

24. Arifah; Salman, D.; Yassi, A.; Demmallino, E.B. Livelihood Vulnerability of Smallholder Farmers to Climate Change: A Comparative Analysis Based on Irrigation Access in South Sulawesi, Indonesia. *Regional Sustainability* **2022**, *3*, 244–253, doi:10.1016/j.regsus.2022.10.002.
25. Arfadly, A.R.; Zubair, H.; Mahyuddin; Soma, A.S. Socio-Economic Vulnerability Level in the Jeneberang Watershed in Gowa Regency, South Sulawesi Province, Indonesia. *Regional Sustainability* **2024**, *5*, 1–11, doi:10.1016/j.regsus.2024.03.007.
26. Widiono, S.; Wahyuni, E.S.; Kolopaking, L.M.; Satria, A. Livelihood Vulnerability of Indigenous People to Climate Change around the Kerinci Seblat National Park in Bengkulu, Indonesia. *Regional Sustainability* **2024**, *5*, 100181, doi:10.1016/j.regsus.2024.100181.
27. Estiningtyas, W.; Mulyani, A.; Sumaryanto; Kartiwa, B. Assessing the Vulnerability of Food Farming System to Support Climate Change Adaptation: A Case Study in Java, Indonesia. *IOP Conference Series: Earth and Environmental Science* **2021**, *648*, 1–10.
28. Munandar, A.I.; Lubis, M.Z.N. The Vulnerability of Rice Distribution in West Java Province, Indonesia: An Intelligent Analysis. *IOP Conference Series: Earth and Environmental Science* **2021**, *724*, 1–7.
29. Solihah, L.P.; Ruminta, R.; Wicaksono, F.Y. Vulnerability and Risk Analysis of Climate Change Impacts on Rice Production (*Oryza sativa* L.) in Majalengka Regency. *Kultivasi* **2024**, *23*, 117–125, doi:10.24198/kultivasi.v23i2.46797.
30. Kementerian PPN (Perencanaan Pembangunan Nasional. *Daftar Lokasi dan Aksi Ketahanan Iklim*; Kementerian PPN: Jakarta, ID, 2021;
31. Ani, S.W.; Darwanto, D.H.; Waluyati, L.R.; Masyhuri. Regeneration of Rural Rice Farmers in Central Java Province. *Environmental Challenges* **2024**, *16*, 100971, doi:10.1016/j.envc.2024.100971.
32. Ministry of Agriculture, Republic of Indonesia. Sistem Informasi Penyuluhan Pertanian (SIMLUH). 2023. Available online [data retrieved using registered account]: https://simluh.pertanian.go.id/ (accessed on 5 February 2025).
33. Ahmed, S.K. How to Choose a Sampling Technique and Determine Sample Size for Research: A Simplified Guide for Researchers. *Oral Oncology Reports* **2024**, *12*, 1–7.
34. Ariyarathna, S.M.W.P.K.; Nanayakkara, K.G.M.; Thushara, S.C. The Nexus of Farmers' Sustainable Agriculture Potential and Readiness for More Organic Use in Rice Farming: Insights from Resilience Theory. *Sustainable Environment* **2023**, *9*, 1–31, doi:10.1080/27658511.2023.2273619.
35. Hair Jr, J.F.; Celsi, M.; Money, A.; Samouel, P.; Page, M. *Essentials of Business Research Methods*, 3rd ed.; Routledge: London, UK, 2016; ISBN: 9781138859920.
36. Hair, J.F.; Sarstedt, M. Factors versus Composites: Guidelines for Choosing the Right Structural Equation Modeling Method. *Project Management Journal* **2019**, *50*, 619–624, doi:10.1177/8756972819882132.
37. Abid, M.; Schneider, U.A.; Scheffran, J. Adaptation to Climate Change and Its Impacts on Food Productivity and Crop Income: Perspectives of Farmers in Rural Pakistan. *Journal Rural Studies* **2016**, *47*, 254–266, doi:10.1016/j.jrurstud.2016.08.005.
38. Chimi, P.M.; Mala, W.A.; Fobane, J.L.; Essouma, F.M.; II, J.A.M.; Funwi, F.P.; Bell, J.M. Climate Change Perception and Local Adaptation of Natural Resource Management in a Farming Community of Cameroon: A Case Study. *Environmental Challenges* **2022**, *8*, 1–10, doi:10.1016/j.envc.2022.100539.
39. Mobeen, M.; Kabir, K.H.; Schneider, U.A.; Ahmed, T.; Scheffran, J. Climate Change Perception, Adaptation, and Constraints in Irrigated Agriculture in Punjab and Sindh, Pakistan. *Mitigation Adaptation Strategies Global Change* **2025**, *30*, 1–27, doi:10.1007/s11027-025-10212-1.
40. Tran, P.T.; Vu, B.T.; Ngo, S.T.; Tran, V.D.; Ho, T.D.N. Climate Change and Livelihood Vulnerability of the Rice Farmers in the North Central Region of Vietnam: A Case Study in Nghe An Province, Vietnam. *Environmental Challenges* **2022**, *7*, 1–13, doi:10.1016/j.envc.2022.100460.
41. Antwi-Agyei, P.; Stringer, L.C. Improving the Effectiveness of Agricultural Extension Services in Supporting Farmers to Adapt to Climate Change: Insights from Northeastern Ghana. *Climate Risk Management* **2021**, *32*, 1–13, doi:10.1016/j.crm.2021.100304.
42. Baffour-Ata, F.; Atta-Aidoo, J.; Said, R.O.; Nkrumah, V.; Atuyigi, S.; Analima, S.M. Building the Resilience of Smallholder Farmers to Climate Variability: Using Climate-Smart Agriculture in Bono East Region, Ghana. *Heliyon* **2023**, *9*, 1–12, doi:10.1016/j.heliyon.2023.e21815.

43. Birner, R.; Davis, K.; Pender, J.; Nkonya, E.; Anandajayasekeram, P.; Ekboir, J.; Mbabu, A.; Spielman, D.J.; Horna, D.; Benin, S.; et al. From Best Practice to Best Fit: A Framework for Designing and Analyzing Pluralistic Agricultural Advisory Services Worldwide. *The Journal of Agricultural Education and Extension* **2009**, *15*, 341–355, doi:10.1080/13892240903309595.
44. Darma, R.; O'Connor, P.; Akzar, R.; Tenriawaru, A.N.; Amandaria, R. Enhancing Sustainability in Rice Farming: Institutional Responses to Floods and Droughts in Pump-Based Irrigation Systems in Wajo District, Indonesia. *Sustainability* **2025**, *17*, 1–22, doi:10.3390/su17083501.
45. Hua, H.H.; Brown, P.R. Social Capital Enhances the Resilience of Agricultural Cooperatives: Comparative Case Studies in the Mekong Delta, Vietnam. *World Development Sustainability* **2024**, *5*, 1–10, doi:10.1016/j.wds.2024.100170.
46. Tanti, P.C.; Jena, P.R. Perception on Climate Change, Access to Extension Service and Energy Sources Determining Adoption of Climate-Smart Practices: A Multivariate Approach. *Journal Arid Environments* **2023**, *212*, 104961, doi:10.1016/j.jaridenv.2023.104961.
47. Hendrawan, D.; Chrisendo, D.; Musshoff, O. Strengthening Oil Palm Smallholder Farmers' Resilience to Future Industrial Challenges. *Scientific Reports* **2024**, *14*, 1–11, doi:10.1038/s41598-024-62426-z.
48. Guthrie, G. Farm Debt and the Over-Exploitation of Natural Capital. *Resource and Energy Economics* **2024**, *77*, 101439.
49. Awazi, N.P.; Quandt, A.; Kimengsi, J.N. Endogenous Livelihood Assets and Climate Change Resilience in the Mezam Highlands of Cameroon. *GeoJournal* **2023**, *88*, 2491–2508, doi:10.1007/s10708-022-10755-9.
50. Tong, Q.; Yuan, X.; Zhang, L.; Zhang, J.; Li, W. The Impact of Livelihood Capitals on Farmers' Adoption of Climate-Smart Agriculture Practices: Evidence from Rice Production in the Jianghan Plain, China. *Climate Risk Management* **2024**, *43*, 1–17, doi:10.1016/j.crm.2023.100583.
51. Slijper, T.; de Mey, Y.; Poortvliet, P.M.; Meuwissen, M.P.M. From Risk Behavior to Perceived Farm Resilience: A Dutch Case Study. *Ecology and Society* **2020**, *25*, 1–36, doi:10.5751/ES-11893-250410.
52. Darnhofer, I. Resilience or How Do We Enable Agricultural Systems to Ride the Waves of Unexpected Change? *Agriculture Systems* **2021**, *187*, 1–5, doi:10.1016/j.agsy.2020.102997.