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Research article

Understanding farmers' risk perception and attitude: A case study of rubber farming in West Kalimantan, Indonesia

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Abstract: Indonesian rubber farming has the largest area in the world, but its implementation faces various risks that decrease productivity and farm income. This study is designed to specify the risk perception, risk attitude and determinant factors for smallholder rubber farmers. The research location was in four subdistricts in West Kalimantan Province, with a sample size of 200 farmers. Data collection was carried out by interview using a structured questionnaire. The risk matrix, Holt and Laury's method and the logit model were used to identify risk perception, risk attitude and determinant factors. The study results showed that most rubber farmers were risk-averse and perceived climate change, plant diseases and price change as high risks. The logit model found that farmers' age, education, rubber plantation size, rubber age, distance and use of rubber clones had a positive and significant effect on farmers' risk perception, while the family size and farming experience had a negative effect. Regarding risk attitude, the logit model found that rubber age, distance and risk perception of price change had a positive and significant effect on farmers' risk aversion, while farmers' age and use of rubber clones had a negative effect. This study recommends providing informal education to the farmers through training and counseling, encouraging the farmers to replant old or damaged rubber trees and adopt rubber clones. Furthermore, it is also necessary to improve road facilities and infrastructure, communication and transportation access to facilitate farming activities.

Keywords: Holt Laury; logit model; risk aversion; risk perception; smallholder rubber farmer

1. Introduction

Risk and uncertainty are significant issues in the agricultural sector [1,2], which cause vulnerabilities in yields and losses in crop production [2–4]. Risks in the agricultural sector can affect the input and output allocation decisions [2], affect farmers' household income [5,6] and cause unstable economic growth in developing countries [7]. In the last few years, risks in the agricultural sector have continued to rise, making it essential for farmers to manage the risks and keep farming activities stable [6,8,9].

The risks faced by farmers significantly affect an individual's decision-making behavior, which may differ from the actual condition. Farmers often make decisions based on their feelings, expectations and observation [10]. The assessment of agricultural risks is critical for two reasons. First, a risk strategy cannot be evaluated based on the expected outcomes without considering the magnitude of the risks. Second, risk assessment can help farmers develop effective risk strategies to reduce the likelihood of significant losses and avoid extreme events, such as business bankruptcy [11].

Risk assessment can be conducted by identifying farmers' risk perception based on farming experience, observation and learning from previous events [11–13]. This assessment is beneficial for stakeholders and policymakers in understanding environmental conditions [14], addressing agricultural risks [15,16] and planning an efficient risk strategy [9,17]. Huet et al. and The World Bank [7,18] suggested two indicators to identify risk perception in the agricultural sector based on risk likelihood and consequences. It is essential to assess these indicators, as farmers can have the same perception regarding risk probability but different in evaluating the impact [19]. In addition, Sjoberg et al. [20] stated that accurate and precise risk perception could raise farmers' ability to predict and manage risks.

Furthermore, agricultural decision-making is also based on risk attitudes [2,17,21], whether farmers are risk-averse, risk-neutral or risk-taking. The difference in risk attitude is closely related to the farmers' financial condition and readiness to face the consequences of profit or loss from taking risks. A risk-averse attitude becomes a reasonable option for farmers with small capital and inability to accept losses, but this can be problematic for farmers' income and well-being [12]. Risk aversion will also impact the inefficient allocation of resources and business management decisions [11].

The subject of this study is Indonesian rubber farming, which has the largest rubber area in the world and produces around 23.8% of the world's rubber supplies [22]. Indonesian total rubber exports in 2020 were recorded at 2.28 million tonnes, with an export value of US$ 3.01 billion [22]. The export destinations for rubber include the United States, Japan, China, India and other countries. In Indonesia, most rubber plantations (90%) are handled by 2.3 million smallholder farmers [22]. These conditions were also similar in other rubber-producing countries, such as Thailand [23], Malaysia [24–26] and China [27–29]. Smallholder farmers are characterized by a lack of capital, low assets and poor managerial skills, which makes them vulnerable to price fluctuations and market uncertainties [25,26,30]. Based on statistical data, Indonesia has the largest rubber area in the world. However, rubber production is in the second position after Thailand, which shows low rubber productivity in Indonesia [22]. Rubber productivity in Indonesia in 2020 was 1,018 kg/ha/year [22], while rubber-producing countries such as Thailand and Malaysia have higher productivity.

The low productivity of rubber plantations is due to various risk factors, such as climate change, plant disease and price change risks [31]. The climate change risk in rubber farming is related to high rainfall and rainy days, causing a decrease in tapping frequency and latex productivity [24,32,33]. The disease risks in rubber plants are rubber leaf fall and white root fungus, causing a decrease in rubber productivity [34–36]. The price change risk is related to the decline in rubber prices influenced by global market conditions. In 2011, the rubber price reached its highest value and has continued to decline until now [37–40]. The increasing volatility in rubber prices and a long period of low prices are thought to be among the main reasons for the decline in production [30,38,40–42]. The rubber price decline also decreases household income, farmers' welfare and purchasing power for primary and secondary goods [28,31].

The risk accumulation can cause production variability and affect productivity and farm income. Therefore, we address this study to understand rubber farmers' environmental conditions and direct the appropriate risk management. The research objective was to identify farmers' risk perception, risk attitude and determinant factors for smallholder rubber farmers. The study's findings assist stakeholders and policymakers in comprehending the risk and facilitate providing the farmers with programs and policies to mitigate the risks. Furthermore, this paper enriches the literature on risk perception and attitude in the agricultural sector in three ways. First, it focused on plantation crops (especially rubber crops), while previous studies were concerned with food crops [1,11,43,44], fishery [12,45,46] and livestock [10,47,48]. Second, the study identified perceptions based on each type of risk because the risk differences will affect the risk perception [2,11,15,43]. Third, the study identifies risk perceptions and attitudes that are critical in shaping the management capabilities of farmers and directs appropriate decision-making in addressing agricultural risks [15,16].

1.1. Farmers' risk perception and risk attitude

Risk refers to uncertain consequences or the likelihood of exposure leading to unfavorable conditions [6]. Previous research mainly focused on two risk categories: production risk and market risk [5,9]. Production risk occurs due to factors related to biological, ecological and technological changes [5,7,49]. This risk is closely associated with climate variability [4,50–53] and plant diseases [2,4,9,11]. Market risk is related to the fluctuation and volatility of input and output prices in farming activities [11,13,47,51]. Market risk often burdens farmers because the causative factors are beyond farmers' control and directly impact household income [5,49]. Multiple agricultural risks can happen simultaneously, so several policy interventions are needed to overcome these risks.

Decision-making in risky situations always makes a trade-off between losses and profits. If there is a possibility of experiencing losses, then there is an opportunity to get profit. Farmers must be able to decide on various alternative strategies that can be done with multiple risks. The ability of farmers to deal with risk depends mainly on risk perception, which is influenced by farming experience, observation and learning from previous events [11,12]. Risk perception is a person's subjective assessment of the probability and consequence of an event [7]. Every risk perception can differ depending on farmer and farm characteristics [19]. Previous research has found determining factors of farmers' risk perception, such as farmers' age [2,11,15,44], education [44,54], farming experience [2,44,54–56], farm area [11,44,54,55] and family size [2,44].

Differences in perceptions of each farmer will determine farmers' risk attitudes and strategies for dealing with risks. Risk attitude is a person's response due to their perception while facing significant risk [57]. An individual's attitude will vary depending on how the individual or group understands the risks. A situation that is considered too risky by one person can be regarded as less risky and acceptable to others [57]. Risk attitudes are generally grouped into three categories: risk averse, risk neutral, and risk loving [58]. Being risk-averse is a typical attitude shown by most smallholder farmers [1,2,11,16,21]. Farmers' risk attitudes are relevant to their decision to adopt risk strategies [21,53]. A risk-averse farmer will avoid the risks and try to reduce, transfer or avoid the risks [59]. A risk-averse attitude becomes an obstacle for farmers in increasing their income and household welfare [12], impacting the inefficient allocation of resources and the ability to mitigate the risks [11]. Based on previous studies, farmers' risk aversion is influenced by various factors, such as age [2,15,44,47], education [2,15,44,47,48], farming experience [16,44], farm size [16,21,47], family size [16,21] and farmers' risk perception [16].

2. Materials and methods

2.1. Research area

The research was conducted from October 2021 until March 2022. The research location was selected in West Kalimantan Province, as one of the main centers for rubber plantations in Indonesia, with contributions to land area and rubber production of 10.68% and 8.27%, respectively [22]. Furthermore, the implementation of rubber farming in this region has experienced various risks, causing low rubber productivity (960 kg/ha/year), which is lower than Indonesia's productivity (1,018 kg/ha/year) [60]. The risks of climate change, plant disease attacks and decreased rubber prices have resulted in low productivity in West Kalimantan [61].

2.2. Sampling framework and data collection

The research location was selected using a multistage sampling technique. The first step is to determine the location of the district with the criteria for the main rubber production center in West Kalimantan, namely, in Sanggau, Sintang and Sambas districts, with contributions of 23.87%, 15.03%, and 6.64% of the total production, respectively [62]. The second step determines the subdistrict's site: Balai and Parindu in Sanggau district, Sepauk in Sintang district and Sajad in Sambas district (Figure 1). The selection of subdistricts considers the main area for rubber production in each district. In addition, the selected locations also have a Rubber Processing and Marketing Unit (RPMU), which helps farmers to improve rubber quality and acts as an intermediary for farmers to market rubber directly to factories. Next, in the third step, we select the sample using simple random sampling based on the proportional size of the rubber farmers' population in each subdistrict. The selected sample was 200 farmers (53 farmers in Balai, 49 in Sepauk, 50 in Parindu and 48 in Sajad).

Data collection was carried out by individual interviews with farmers using questionnaires that contain three main sections. Section 1 is about farmers and farm characteristics. Section 2 includes indicators to assess risk perceptions based on risk likelihood and consequences. Section 3 contains Holt and Laury's experiment to identify risk attitudes. The data included in the questionnaires (farmers, farm characteristics and indicators) were based on a literature review. The pretest questionnaire was conducted to test the validity and reliability using 30 samples, and the findings indicated that the instrument was valid and reliable.

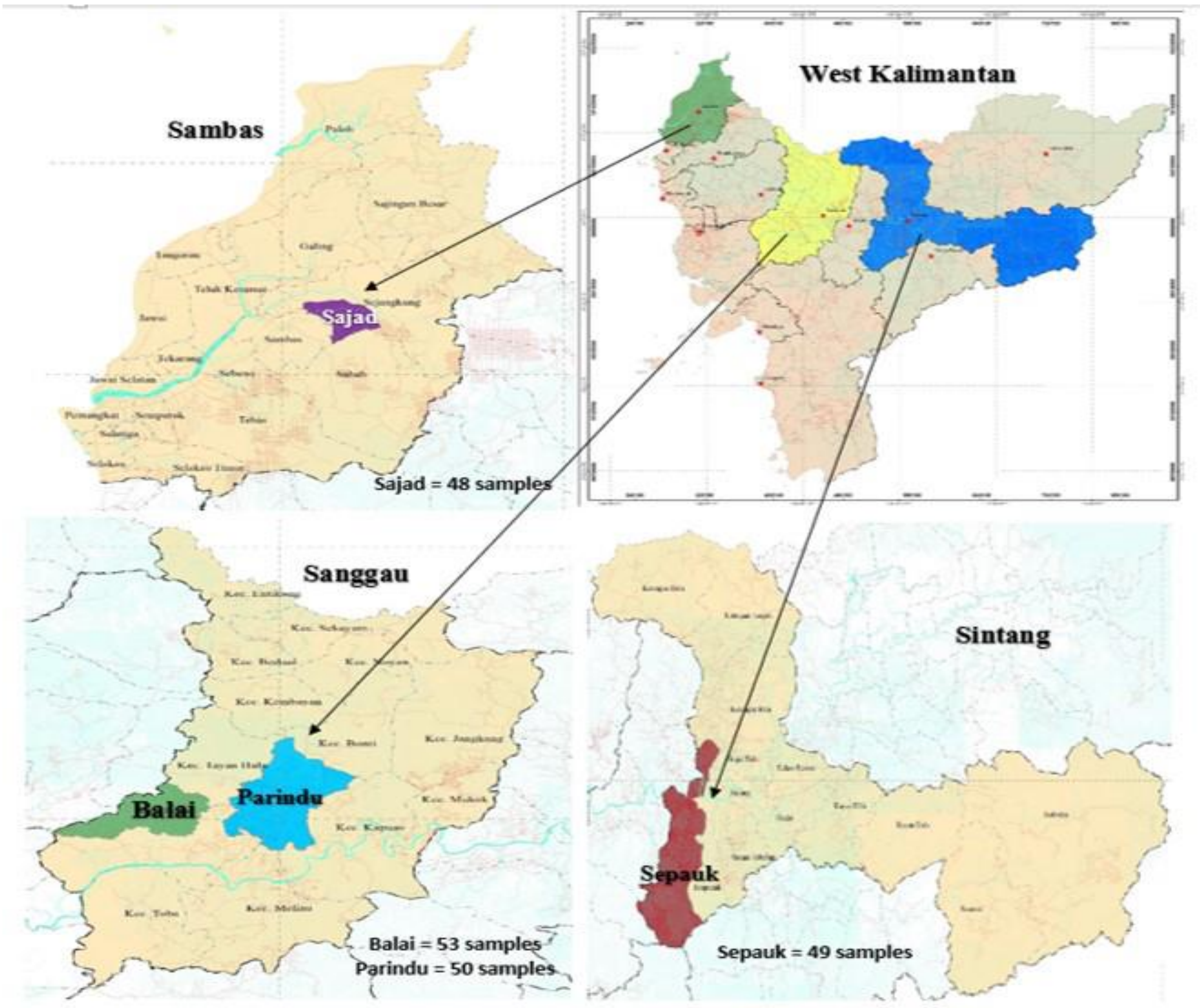

Figure 1. Map of the research area.

2.3. Data analysis

2.3.1. Risk perception

The measurement of risk perception was carried out for climate change, plant disease and price change risks based on their likelihood and consequence using a Likert scale, as presented in Table 1. The likelihood category is based on the percentage of risk probability in rubber farming with a percentage of 0–100% and then divided by the number of classes. Consequence categories were based on the percentage of losses in yields due to risk, and the indicators were adopted from The World Bank's guidelines in agricultural risk assessment [7]. Following earlier studies from Akhtar et al. and Khan et al. [11,17], the next step of risk assessment is combining the two indicators using a risk matrix and determining the risk category (Figure 2). A risk matrix is compiled by placing the likelihood score on the vertical dimension and the consequence score on the horizontal dimension and then adding up the scores to get a total score of 2–10. The risk is low if the total score is 2–5 and high if the total score is 6–10 [2,11,17]. The total score was calculated for each farmer for each type of risk because farmers can have different perceptions of different risk types.

Table 1. Risk likelihood and consequence category.

Likert scale	Likelihood category	Consequence category
5	Very often (risk probability ≥ 80%)	Very high (losses in yields ≥ 50 %)
4	Often (risk probability 60–80%)	High (losses in yields 30–50%)
3	Occasionally (risk probability 40–60%)	Middle (losses in yields 15–30%)
2	Rare (risk probability 20–40%)	Low (losses in yields 5–15%)
1	Very rare (Risk probability 0–20%)	Very low (losses in yields < 5%)

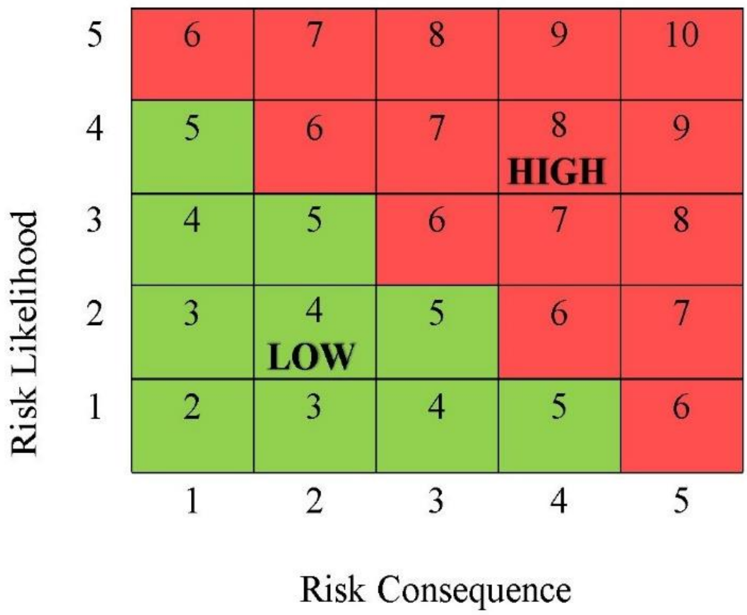

Figure 2. Risk matrix.

2.3.2. Risk attitude

Risk attitude analysis was conducted using Holt and Laury's experiments, and other researchers have widely used this method [12,47,63,64]. Experiments were designed explicitly by modifying the Holt and Laury method based on agricultural activities in the research area. Farmers were asked to select between two types of farming activities (A and B), as presented in Table 2. The A activity generates IDR 1,083,000 (highest income) and IDR 733,300 (lowest income), while the B activity generates IDR 1,616,700 (highest income) and IDR 366,700 (lowest income). Respondents were asked to choose between two options (choice A or B) 10 times in each scenario with a different income probability. The probability of generating the highest income increased from 0% to 100% (probability 1). In contrast, the probability of generating the lowest income decreased from 100% to 0% (probability 2).

Table 2. The scenario of measuring farmers' risk attitude in Holt and Laury's experiments.

Scenario	Probability 1 vs. Probability 2	Activity A (IDR)	Activity B (IDR)	Net expected value	CRRA ranges	Risk aversion class
1	10% vs 90%	1,083,000 vs 733,300	1,616,700 vs 366,700	276,600	r < −2.06	RL4
2	20% vs 80%	1,083,000 vs 733,300	1,616,700 vs 366,700	186,600	−2.06 < r ≤ −1.13	RL3
3	30% vs 70%	1,083,000 vs 733,300	1,616,700 vs 366,700	96,600	−1.13 < r ≤ −0.53	RL2
4	40% vs 60%	1,083,000 vs 733,300	1,616,700 vs 366,700	6,600	−0.53 < r ≤ −0.04	RL1
5	50% vs 50%	1,083,000 vs 733,300	1,616,700 vs 366,700	−83,400	−0.04 < r ≤ 0.41	RN
6	60% vs 40%	1,083,000 vs 733,300	1,616,700 vs 366,700	−173,400	0.41 < r ≤ 0.85	RA1
7	70% vs 30%	1,083,000 vs 733,300	1,616,700 vs 366,700	−263,400	0.85 < r ≤ 1.32	RA2
8	80% vs 20%	1,083,000 vs 733,300	1,616,700 vs 366,700	−353,400	1.32 < r ≤ 1.88	RA3
9	90% vs 10%	1,083,000 vs 733,300	1,616,700 vs 366,700	−443,400	1.88 < r ≤ 2.72	RA4
10	100% vs 0%	1,083,000 vs 733,300	1,616,700 vs 366,700	−533,400	2.72 < r	RA5

Source: Author's calculation.

The net expected value of each respondent's choice was calculated as follows (equation 1):

$$\text{Net expected value} = \sum_{s=1}^{2} P(A_s)A_s - \sum_{s=1}^{2} P(B_s)B_s \tag{1}$$

For each activity (A or B), s = 1 indicates the preferred condition with the highest income, and s = 2 indicates the unpreferred condition with the lowest income. Both options have high and low expected values, but activity B has a higher risk (variance) because the expected yield varies more than A. Therefore, the A activity is considered a relatively safe option, and the B activity is risky. The expectation of B activity increases relative to the A activity when the question continues to the following scenario. Furthermore, this experiment assumes constant relative risk aversion / CRRA (r), which was defined (equation 2) as follows [47,64]:

$$(x) = \frac{x^{1-r}}{1-r} \tag{2}$$

The number of options in the A activity illustrates the risk attitude. Risk-taker farmers select the safe choice (the A activity) fewer than five times, whereas risk-averse farmers select the A activity more than five times. Risk-indifferent farmers will select the A activity five times and switch to riskier alternatives (the B activity) [53,64,65]. The questionnaires were visualized using colored images to make it easier for respondents to understand this experiment [63].

2.3.3. Factors determine risk perception and risk attitude

Following the previous study by Huong et al. [54] and focusing on the dichotomous dependent variable, this research applied the logit model to identify the determinant factors of farmers' risk perception and attitude. Based on Hosmer et al. [66], the logit model is written in equations 3 and 4:

$$P_i = E(Y = 1|X) = \frac{1}{1 + e^{-(\beta_0 + \beta_i X_i)}} = \frac{1}{1 + e^{-Z_i}} \quad (3)$$

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \mu_i \quad (4)$$

where P_i is the probability of farmers' risk perception and attitude, β_0 is an intercept, and β_1, β_2 and β_n are the estimated coefficients. X_1, X_2, … and X_n are explanatory variables, and μ_i is the error term. Logit analysis was carried out four times: risk perception analysis for three different types of risk (climate change, plant disease and price changes) and risk attitude analysis. This study uses independent variables adopted from previous studies (farmers' age, education, family size, farm experience, farm size) combined with characteristics of rubber farming (rubber age, rubber plantation distance and use of rubber clones). Because the model was derived from the logit distribution, it is precise to measure the impact of the independent variables on the outcome probability, called the marginal effects. The marginal effects are calculated in equation 5 [67]:

$$\frac{\delta E\ (Y|X)}{\delta X} = \frac{e^{\beta_0 + \beta_i X_i}\beta_i}{1 + e^{\beta_0 + \beta_i X_i}}\left(1 - \frac{e^{\beta_0 + \beta_i X_i}\beta_i}{1 + e^{\beta_0 + \beta_i X_i}}\right) = \frac{e^{\beta_0 + \beta_i X_i}\beta_1}{\left(1 + e^{\beta_0 + \beta_i X_i}\right)^2} \quad (5)$$

The logit model was calculated using the maximum likelihood estimation and STATA 16 software. Before starting the analysis, we verified for multicollinearity using the Variance Inflation Factor and Tolerance test. The results showed that there was no multicollinearity in the model.

3. Results

3.1. Descriptive statistics

Table 3 presents the descriptive statistics of explanatory variables in this research. Farmers' and farm characteristics have important influences on the farmers' ability to assess and mitigate the risk [17]. In this study, farmers are in the productive age category (44 years), with a minimum of 25 years and a maximum of 75 years. Farmers' age generally affects their physical condition, mindset and ability to adopt technologies and innovations in farming activities. Farmers have an average of eight years of schooling (with a minimum of 2 years and a maximum of 17 years), but at least they can read, write and count, which can assist them in managing their farms. Farmers have an average experience of 17 years (with a minimum of 7 years and a maximum of 50 years). Even though farmers' education is relatively low, farmers have a high level of farming experience, which can help them to assess and mitigate the risks.

In terms of farm size, farmers have an average of 1.49 hectares of rubber area (minimum of 1 hectare and maximum of 3 hectares), owned privately and managed by farmers and their household members. Farmers have an average of four family members (with a minimum of 2 persons and a maximum of 7 persons). If the family members were in productive age, they could be alternative labor for farming activities. Most farmers have rubber trees in their productive age of 10-20 years, with an average of 13 years, thereby giving farmers opportunities to increase rubber production and farm income. The mean distance from the rubber plantation to the village center was 2.32 km (with a minimum of 0.5 km and a maximum of 6 km). From the interview results, farmers tap the trees quite often (at least every two days and sometimes more), and the distance is more important in this situation. The long distance from the rubber plantation to the village center will make it difficult for farmers to maintain and tap the trees. Next, the study results indicated that most rubber farmers (76%) use rubber clones (PB 260), and the rest use local seeds. These results were similar to earlier research which stated that the use of cloned rubber in Indonesia is still low, resulting in lower productivity [68].

Table 3. Descriptive statistics.

Variables	Description	Min	Max	Mean	Std. Dev.
Farmers' and farm characteristics					
Farmers' age	Age of farmer (years)	25	75	43.85	9.17
Education	Formal education of farmer (years)	2	17	8.2	2.43
Family size	Number of family members (persons)	2	7	4.46	1.03
Farming experience	Farming experience (years)	7	50	17.34	7.45
Rubber plantation size	Total rubber plantation area (hectares)	1	3	1.49	0.50
Rubber age	Age of rubber trees (years)	6	27	13.08	4.00
Distance (km)	The distance from the plantation to the village center (km)	0.5	6	2.32	1.11
Use of rubber clone	1 = apply rubber clone, 0 = otherwise	0	1	0.76	0.43
Risk perception					
Climate change	1 = if perceived as high risk, 0 = otherwise	0	1	0.81	0.40
Plant disease	1 = if perceived as high risk, 0 = otherwise	0	1	0.69	0.46
Price change	1 = if perceived as high risk, 0 = otherwise	0	1	0.75	0.43
Risk attitude					
Risk aversion	1 = risk averse, 0 = otherwise	0	1	0.80	0.40

Source: Data analysis, 2022.

The farmers' risk perception results showed that most farmers perceive climate change, plant diseases and price changes as high risks, with percentages of 81%, 69% and 75%, respectively. The details of farmer risk perception based on the likelihood and consequence categories are presented in Figures 3 and 4. Regarding the risk of climate change, most farmers (48%) perceived the risk probability in the occasional category and the risk consequence in the middle category (48%). The probability response in the often-very often happens categories was 35.5%, and the response in the rare-very rare categories was 16.5%. In the risk consequence response, the response in the high-very high categories was 31%, and the response in the low-very low categories was 21%. This result shows that most farmers perceive climate change as an occasional-often risk with a middle-high impact on yield loss, and based on the risk matrix, this risk was categorized as high risk.

Regarding the risk of plant diseases, most farmers (42.5%) perceived the risk probability in the occasional category and the risk consequence in the middle category (39%). The probability response in the often-very often happens categories was 30.5%, and the response in the rare-very rare categories was 27%. In the risk consequence response, the response in the high-very high categories was 17.5%, and the response in the low-very low categories was 43.5%. This result shows that most farmers perceive plant diseases as an occasional-often risk but with a low-middle impact on yield loss. In the risk matrix, even though the risk has a low-middle impact on farming, if the risk probability is in the occasional-often category, then the risk is categorized as high risk.

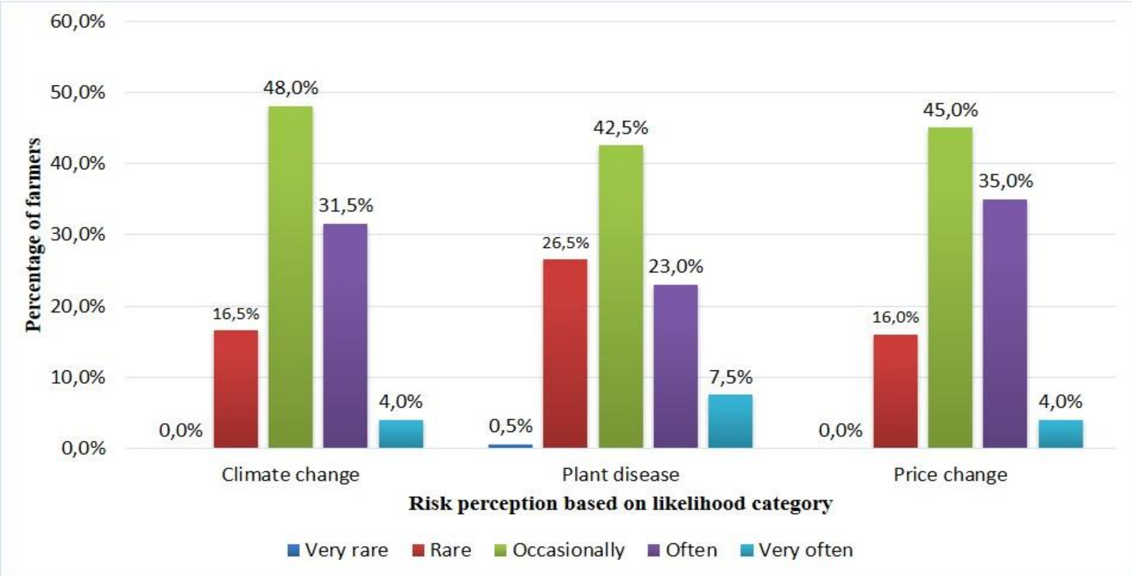

Figure 3. Risk perception based on likelihood category.

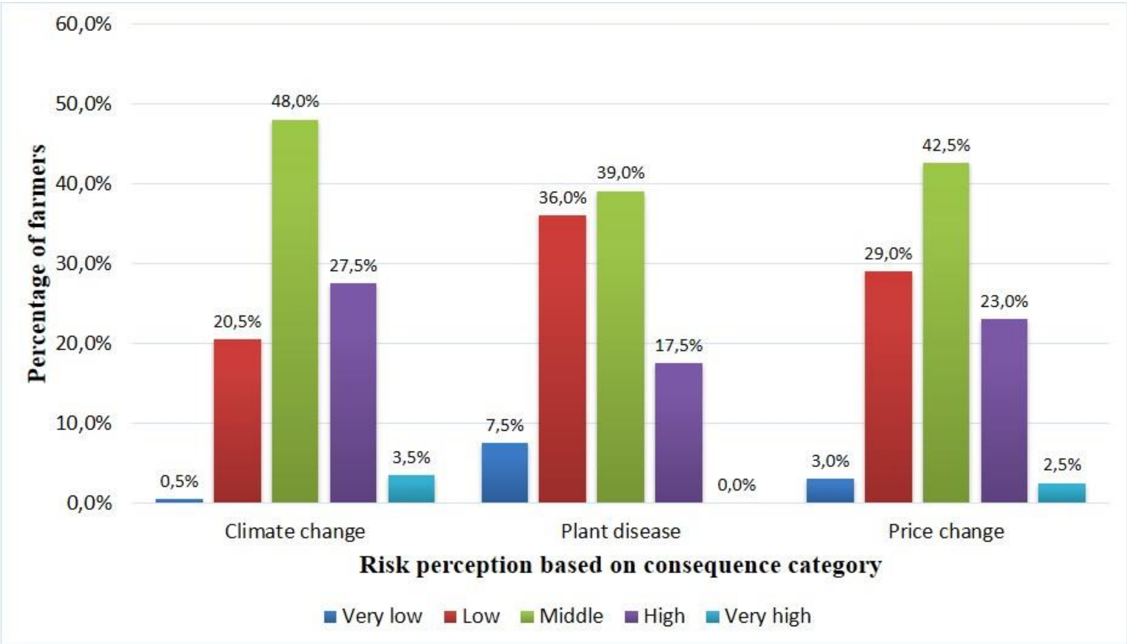

Figure 4. Risk perception based on consequence category.

Regarding the risk of price changes, most farmers (45%) responded to the risk probability in the occasional category and the risk consequence in the middle category (42.5%). The response in the probability categories of often or very often happens was 39%, and the response in the rarely-very rarely categories was 16%. In the risk impact category, the high-very high response was 25.5%, and the low-very low response was 32%. This result shows that most farmers perceive price changes as an occasional-often risk but with a low-middle impact on yield loss. Based on the risk matrix, this risk is categorized as high risk. Other findings in Holt and Laury's method showed that most rubber farmers were risk-averse (80%), only 5.5% were risk-loving, and the rest were risk-neutral (14.50%).

3.2. Factors determining farmers' risk perception

The logit model results in Tables 4 and 5 present the parameter estimates and marginal effects of the influences of farmers and farm characteristics on risk perceptions and attitudes. Marginal effects provide a more detailed discussion about the average effect of changes in independent variables on the change in the outcome probability. Based on the logit results, all ρ values were less than 0.000, meaning that the models are fit. In addition, Pseudo R-squared in the model ranges from 0.300 to 0.446, showing that the models are fit to clarify the risk perception and attitude.

Table 4. Estimates of the parameters from the logit models.

Variable	Risk perception			Risk attitude
	Climate change	Plant disease	Price change	
Farmers' and farm characteristics				
Farmers' age	0.094**(0.042)	0.116***(0.036)	0.168***(0.044)	−0.195***(0.054)
Education	−0.124 (0.097)	−0.139 (0.088)	0.566***(0.130)	−0.174 (0.138)
Family size	−0.481**(0.245)	0.045 (0.204)	−1.108***(0.286)	0.449 (0.330)
Farming experience	−0.263***(0.058)	−0.170***(0.047)	−0.063 (0.048)	−0.026 (0.059)
Rubber plantation size	−0.668 (0.490)	1.137***(0.414)	−0.546 (0.479)	0.338 (0.574)
Rubber age	−0.090 (0.066)	0.134**(0.066)	0.173**(0.079)	0.687***(0.137)
Distance	0.671*** (0.267)	0.889***(0.220)	0.717***(0.258)	0.552** (0.277)
Use of rubber clone	−0.218 (0.642)	−1.744***(0.631)	1.672***(0.557)	−2.421***(0.852)
Risk perception				
Climate change	NA	NA	NA	−0.235 (0.953)
Plant disease				−0.902 (0.646)
Price change				1.499**(0.617)
Constant	6.636***(2.179)	−3.985**(1.760)	−8.37***(2.137)	2.105 (2.552)
LR statistic (Prob)	65.869***	74.326***	72.991***	89.313***
R-squared	0.339	0.300	0.328	0.446

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, standard errors in parentheses. Source: Data analysis, 2022.

Farmers' age has a significant and positive effect on risk perceptions of climate change ($p < 0.05$), plant disease ($p < 0.01$) and price change ($p < 0.01$). The marginal effects show that a unit increase in the farmers' age will increase farmers' probabilities of perceiving climate change, plant diseases and price change as high risks by 0.9%, 1.6% and 2.0%, respectively. Farmers' education significantly affects price change risk perception ($p < 0.01$) but not that for climate change and plant disease. The marginal effects show that a unit increase in education will increase farmers' probability of perceiving price change as high risk by 6.8%. Regarding family size, the logit results found that this variable has a significant negative effect on risk perception of climate change ($p < 0.05$) and price change ($p < 0.01$) but not for plant disease. According to the marginal effects, a unit increase in family members will decrease the farmers' probabilities of perceiving climate change and price change as high risks by 4.8% and 13.3%, respectively.

Table 5. Marginal effects from the logit models.

Variable	Risk perception			Risk attitude
	Climate change	Plant disease	Price change	
Farmers' and farm characteristics				
Farmers' age	0.009**(0.004)	0.016***(0.005)	0.020***(0.005)	−0.017***(0.004)
Education	−0.012 (0.009)	−0.019 (0.012)	0.068***(0.013)	−0.015 (0.012)
Family size	−0.048**(0.024)	0.006 (0.029)	−0.133***(0.029)	0.039 (0.028)
Farming experience	−0.026***(0.005)	−0.024***(0.006)	−0.008 (0.006)	−0.002 (0.005)
Rubber plantation size	−0.066 (0.048)	0.161***(0.054)	−0.655 (0.057)	0.029 (0.049)
Rubber age	−0.009 (0.007)	0.019**(0.009)	0.021**(0.009)	0.059***(0.008)
Distance	0.067*** (0.025)	0.126***(0.026)	0.086***(0.029)	0.048**(0.023)
Use of rubber clone	−0.021 (0.061)	−0.227***(0.065)	0.222***(0.072)	−0.173***(0.044)
Risk perception				
Climate change	NA	NA	NA	−0.020 (0.078)
Plant disease				−0.075 (0.050)
Price change				0.144**(0.062)

*** p < 0.01, ** p < 0.05, * p < 0.1, standard errors in parentheses. Source: Data analysis, 2022.

In the case of farming experience, this variable has a negative effect on the risk perception of climate change ($p < 0.01$) and plant disease ($p < 0.01$). The marginal effects show that a unit increase in farming experience will decrease the farmers' probabilities of perceiving climate change and plant disease as high risks by 2.6% and 2.4%, respectively. Rubber plantation size positively affects the risk perception of plant disease ($p < 0.01$), and the marginal effects show that a unit increase in rubber area will increase the farmers' probability of perceiving plant disease as high risk by 16.1%. Rubber age positively affects the risk perception of plant disease ($p < 0.05$) and price change ($p < 0.05$). The marginal effects show that a unit increase in rubber age will increase farmers' probabilities of perceiving plant diseases and price change as high risks by 1.9% and 2.1%, respectively.

The distance from the rubber plantation to the village center positively affects all risk perceptions ($p < 0.01$), which means that farmers whose plantations are far from the village center tend to perceive climate change, plant diseases and price changes as high risks. The marginal effects show that a unit increase in rubber plantation distance will increase the farmer's probabilities of perceiving climate change, plant diseases and price change as high risks by 6.7%, 12.6% and 8.6%, respectively. The study results also indicated that using a rubber clone affects risk perception differently. This variable positively affects the price change risk perception ($p < 0.01$) but negatively affects that of plant disease ($p < 0.01$). The marginal effects show that if farmers use rubber clones, they will have a 22.2% higher probability of perceiving price change as high risk and a 22.7% lower probability of perceiving plant diseases as high risk.

3.3. Factors determining farmers' risk attitude

Tables 4 and 5 also describe the determinant factors of farmers' risk attitudes. Farmers' age negatively affects risk aversion ($p < 0.01$), and the marginal effects show that a unit increase in farmers' age will decrease the probability of farmers' risk aversion by 1.7%. In the case of rubber age, this variable positively affects risk aversion ($p < 0.01$), and the marginal effects show that a unit increase in rubber age will increase the probability of farmers' risk aversion by 5.9%. The distance from the plantation to the village center positively affects risk aversion ($p < 0.05$). The marginal effects show that a unit increase in plantation distance to the village center will increase the probability of farmers' risk aversion by 4.8%.

In contrast, using rubber clones negatively affects risk aversion ($p < 0.01$). The marginal effects indicate that if farmers use rubber clones, the probability of their being risk-averse will decrease by 17.3%. Furthermore, the logit models also found that price change risk perception positively affects farmers' risk aversion ($p < 0.05$). The marginal effects indicate that if farmers perceive price change as high risk, they will have a 14.4% higher probability of being risk-averse.

3.4. The schematic framework of research

Figure 5 shows the schematic framework to describe the research comprehensively. The results of parameters and marginal effects in the logit model are summarized in a flowchart. The left and right sides of the framework present the influence of rubber farmers' and farm characteristics on risk perception and attitude, respectively. The flowchart also shows the influence of risk perception on risk aversion. The black connectors in the flowchart indicate a positive effect on the variables, while the red connectors indicate a negative effect. The values in connector lines show the significance levels and marginal effects, and the value in square parentheses for each characteristic shows the variable's mean.

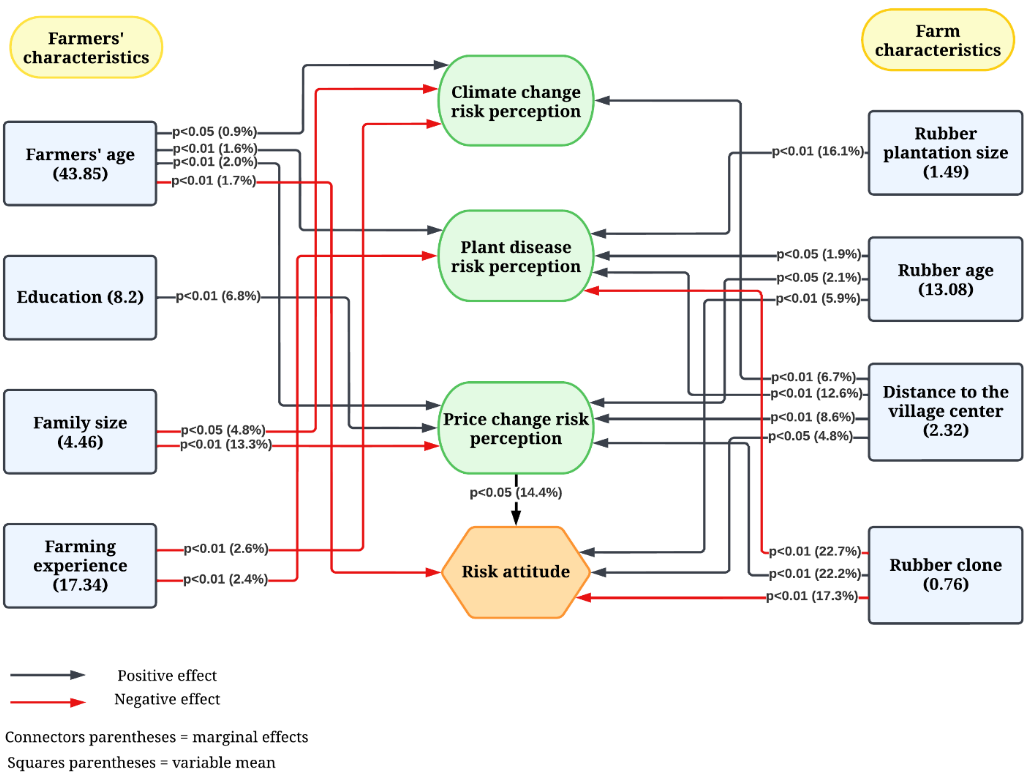

Figure 5. The schematic framework of research.

4. Discussion

This research focuses on three main risks in rubber farming: climate change, plant diseases and price change. The study found that most rubber farmers perceived climate change, plant diseases and price change as high risks. The risk of climate change in rubber plantations is related to increased rainfall and rainy days, significantly affecting farming activities. The rainy season makes it difficult for farmers to tap latex, which reduces latex production. The main climatic factors that affect rubber tapping are rainfall intensity, quantity, time and duration [33]. Farmers typically tap the latex at dawn or very early in the morning. Farmers will delay the tapping if persistent and heavy rain occurs. If the rain occurs during tapping time, rainwater will fall onto the tree flow to the tree trunk and branches and then enter the tapping cup. The tapping results will be wasted since they are mixed with rainwater. If there is frequent rain in a certain period, it will significantly reduce rubber production. Ruangsri et al. and Sdoodee & Rongsawat [23,69] stated that increased rainfall and rainy days in Thailand cause decreases in tapping frequency and rubber productivity. Rubber farmers in Myanmar also experienced the negative impact of climate change on irregular tapping days, low productivity and high tapping cost [32].

Regarding rubber plant diseases, the majority of farmers perceived rubber diseases as high risk. Previous studies reported a severe attack of leaf fall disease, which decreased rubber production in Indonesia, Malaysia, India and Thailand [33,70]. Leaf fall disease also attacks rubber plantations in Latin America, causing repeated defoliation of rubber trees [34]. In Indonesia, leaf fall disease causes leaf drop of up to 75–90%, and rubber production decreases by 25–45% [36]. In addition, rubber trees are also susceptible to white root fungal disease that causes latex yield loss and tree death [71]. Previous research also reported the presence of this disease in several rubber-producing countries, including Malaysia [35,71] and Thailand [72].

Moreover, most rubber farmers also perceived price change as a high risk since it is related to the decline in output prices, which significantly impacts rubber farming. Rubber is an export commodity, and global market conditions influence the rubber price. The fluctuations in rubber prices have led to the vulnerability of rubber farmers' livelihoods in Thailand [38,42], China [29,37], Indonesia [73] and other rubber-producing countries. The decline in rubber prices has a multiplier effect on reduced income, farmers' investment ability, purchasing power and land conversion to more prospective crops [74]. Previous studies highlighted farmers' efforts to overcome the risk and reduce the dependence on rubber farming, for example, through income diversification [37,41,42].

The logit model found that farmers' and farm characteristics were important in shaping the ability of farmers to perceive the risks. Farmers' age and the distance from the plantation to the village center affect all risk perceptions (climate change, plant disease and price change). In the case of several other variables (education, family size, farming experience, rubber plantation size, rubber age and use of rubber clones), there are different findings. One variable can affect the perception of one type of risk but not affect another risk. Previous studies also reported different results regarding the effects of independent variables on different risk perceptions [11,15,54,75,76].

Our logit model found that farmers' age positively affects risk perception. The oldest farmers will perceive climate change, plant disease and price change as a high risk. This finding confirmed previous studies, which showed that farmers' age had a positive effect on the risk perception of climate change [11,43,77,78], plant disease [43] and price change [2,15,76,78]. Elderly farmers generally experience a decrease in physical ability in farming activities. Meanwhile, rubber farming requires more energy and time for tapping and plant maintenance [79]. In a risky situation, it will be more difficult for elderly farmers to run their farms. This is why farmers perceive climate change, plant diseases and price changes as major threats to their rubber farming.

The positive effect of farmers' education on risk perception means that educated farmers perceive price change as a high risk. The same result was similar to previous studies, which found that experienced farmers perceive price change as high risk [14,44]. Education is essential for farmers because it can increase farmers' insight, skills, managerial abilities and technology adoption [80–82]. Based on the survey results, most farmers have low education, which affects their ability to obtain information and technology related to agricultural activities. This variable had no significant effect on the risk perception of climate change and plant diseases. This could happen due to a lack of education, making it difficult for farmers to predict and mitigate the risks. Previous studies also reported different results regarding the effect of education on the different types of risk [11,76]. Since the farmers' formal education is relatively low, this study suggests developing and increasing informal education programs such as training and counseling to increase farmers' knowledge about farming management and risk mitigation.

Furthermore, the family size variable shows a negative effect on risk perception. Farmers with many family members perceive climate and price changes as low risk. A case study in Pakistan also identified the negative effect of family size on risk perception of climate change and price change [2]. Based on our survey, most farmers use family labor (wife, son or other family members) to carry out activities on the rubber plantation: for example, to maintain and tap the rubber. Farmers can save production costs by using labor families, which makes them perceive the climate and price changes as low risk. Research from Tongkaemkaew & Chambon [83] showed the same result, stating that family members are the primary source of labor in smallholder rubber plantations.

Regarding farming experience, this variable has a negative effect on the risk perception of climate change and plant disease, which means that experienced farmers perceived climate change and plant disease as low risk. This result is consistent with previous studies, which stated that experienced farmers show a low-risk perception of climate change [11,56] and plant disease [11,76,78]. In general, experienced farmers can predict the probability of climate change, know the plant disease symptoms, prevent and control the disease and overcome the risk impact. Experienced farmers can also determine the right time to tap during the rainy season and can minimize the possibility of latex mixing with water during the rainy season. On the other hand, this variable does not affect price change risk perception because the rubber price depends on global market prices. Most farmers also sell their rubber through collectors, which makes them not have a bargaining position. The results aligned with previous studies stated that farming experience affects the risk perception of climate change and plant diseases but does not affect the risk perception of price change [56].

The logit analysis also revealed that the rubber plantation area positively affects the risk perception of plant disease. The rubber plant diseases such as leaf fall disease and white root fungus result in decreased latex production [36,71]. Larger farm areas make it difficult for farmers to perform more intensive farm maintenance, making them perceive plant diseases as a high risk. Furthermore, the high costs that farmers must incur to prevent and control rubber plant diseases are the main obstacle to overcoming this risk [35].

Regarding the age of rubber trees, this variable positively affects the risk perception of plant disease and price change. Farmers consider plant disease a high risk since old rubber trees are more prone to disease and produce less latex, mainly after the productive age (20 years) [84]. Furthermore, the decline in production and rubber price will decrease farm income, leading farmers to perceive price changes as a high risk. In contrast, the rubber age has no significant effect on climate change risk. Climate change affects rubber plants throughout their growth period. The rainy season affects farmers' activities in maintaining trees, clearing weeds and tapping [23,33,69].

The distance from the rubber plantation to the village center positively affects risk perceptions. Farmers whose plantations are far from the village center tend to perceive climate change, plant diseases and price changes as high risks. Previous research also found the positive effects of farm distance to the city on risk perception of climate change [15], price change [14,15,44,76] and plant disease [2]. Generally, the village center is the primary location for providing input facilities, marketing and a place to access information. It is difficult for the farmers to perform farm maintenance, tap and transport the rubber to the collector if the farm is far from the village center. Similarly, Akhtar et al. and Iqbal et al. [11,15] stated that farmers near the village center could better access information and communicate more efficiently with input sub-dealers or collectors.

The study results indicated that using a rubber clone affects risk perception differently. This variable positively affects price change risk perception but negatively affects that of plant disease. Adopting rubber clones requires more farm maintenance and inputs than local seeds. Hence, farmers feel difficulties when the output price decreases. On the contrary, farmers who use rubber clones perceived plant disease as low risk because rubber clones are more resistant to disease than the local ones. A similar previous study also stated the potential high production and resistance to disease as advantages of rubber clones [39,68,85].

Based on Holt and Laury's experimental method, we can conclude that most farmers were risk-averse. Farming activities vulnerable to uncertainty are the main reason for farmers' risk aversion. Ouattara et al. [86] stated that under conditions of uncertainty, risk-averse farmers tend to reduce their land allocation for perennial crops and switch to annual crops. In line with this research, Djanibekov & Villamor stated that the higher the farmer's risk aversion, the larger the rubber agroforestry area [87]. Furthermore, Moser & Mubhoff's research found that rubber farmers in Indonesia were risk averse, influencing farmers' decision to use inputs such as fertilizer and herbicide [63]. Risk-averse farmers make production and management decisions that are less risky and with lower returns [21].

Regarding farmers' risk attitude, we found that age has a negative effect on risk aversion, which means that older farmers were less risk-averse. In other words, older farmers are more willing to take risks than young farmers. This might happen due to their confidence and desire to manage their farming activities. The same results were also relevant for farmers in Pakistan [2,15,75]. The variable of rubber age had a positive effect on risk aversion, which means that increasing the rubber age will make farmers more risk averse. Typically, rubber trees start to produce at five years [61]. However, in the case of smallholder farmers with limited input, rubber trees are rarely tapped before seven years. Rubber trees can reach optimal production at 15-20 years, and the production will decrease after 20 years. This condition decreases farm income and makes the farmers more risk-averse. Farmers can increase production by replanting rubber trees older than 30 by using rubber clones. Rubber tree replanting could maintain the productivity of natural rubber by substituting unproductive trees with productive rubber trees [88,89].

The distance from the plantation to the village center positively affected risk aversion, indicating that the location of the plantation being far from the village center will increase farmers' risk aversion. The remote area of the farm will make it difficult for the farmers to carry out farming activities (fertilization, farm maintenance and tapping). It will require additional transportation costs, thus making farmers more risk-averse. Previous research also stated that the farm's distance from the city positively affects risk-averse attitudes [78].

Regarding rubber clones, the results also found that this variable had a negative effect on risk aversion. Farmers who adopt rubber clones are less risk-averse than farmers who use local ones because rubber clones have higher production potential and income. Farmers who use rubber clones show a more adaptive attitude toward innovation and technology, which can encourage the farmers to increase production and income. In the research location, farmers adopted the PB 260 clone. This clone shows the best performance among other clones even in low input conditions, provides more latex and increases rubber productivity [68,85,89]. Given the importance of using rubber clones, this research suggests that the government can develop and reproduce rubber clones and provide motivation and assistance to farmers in using rubber clones [26].

The price change risk perception positively affected farmers' risk aversion. Farmers who perceive price change as high risk will be more risk-averse. The decline in global rubber prices for several years has reduced rubber production and farm incomes. As a result, farmers will perceive price changes as high risk, making them more risk-averse. Previous research conducted by Saqib et al. [16] confirmed this finding, stating that farmers with high-risk perceptions were more risk-averse than farmers with low-risk perceptions.

This study had several limitations. First, this study was based mainly on survey results, perceptions, experimental methods and interviews. Farmers' answers depend on how they understand the questionnaires, which may influence the responses. Second, this study was conducted in West Kalimantan, Indonesia. Studies in other regions in Indonesia with different geographical areas or planting systems will improve the study results. Third, the proposed model could be enhanced for future research in several ways: 1) by adding data regarding farmers' strategies to minimize and mitigate the risks; 2) by adding other explanatory variables which could influence farmers' risk perception and risk attitudes, such as ethnic group and geographical area; 3) by exploring other possible types of risk which have a severe impact in rubber farming, such as financial risk and institutional risk.

5. Conclusions

These study results are valid for smallholder rubber farmers in West Kalimantan Province. However, it may be interesting to study if similar results would be found in other regions of Indonesia and other rubber-producer countries. Based on the risk likelihood and consequence combination, the study results indicated that most rubber farmers perceive climate change, plant disease and price change as high risks. The study also found that most rubber farmers were risk-averse. Logit model estimation found that all models fit, and most of the farmers' and farms' characteristics were significant. Farmers' age, education, rubber plantation size, rubber age, distance from the plantation to the village center and rubber clones positively affected risk perceptions, while family size and farming experience had a negative effect. Regarding risk attitude, the variables of rubber age, distance from the plantation to the village center and price change risk perception positively affected farmers' risk aversion. In contrast, farmers' age and the use of rubber clones had a negative effect.

The study results are important for policymakers, because they consider socio-economic characteristics, risk perceptions and risk attitudes, to develop appropriate policies to help farmers mitigate the risks: for example, increasing informal education programs such as training and counseling. The government and stakeholders can motivate and enable farmers to replant old/damaged rubber trees using rubber clones with higher yield potential and more disease resistance. Additionally, to facilitate farming activities, it is necessary to improve communication, transportation access and road facilities and infrastructure.

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Conflict of interest

The authors state no conflict of interest in this research.

References

1. Adnan KMM, Ying L, Sarker SA, et al. (2020) Simultaneous adoption of risk management strategies to manage the catastrophic risk of maize farmers in Bangladesh. *GeoJournal* 86: 1981–1998. https://doi.org/10.1007/s10708-020-10154-y
2. Fahad S, Wang J, Khan AA, et al. (2018) Evaluation of farmers' attitude and perception toward production risk: Lessons from Khyber Pakhtunkhwa Province, Pakistan. *Hum Ecol Risk Assess* 24: 1710–1722. https://doi.org/10.1080/10807039.2018.1460799
3. Oyetunde-Usman Z, Olagunju KO, Ogunpaimo OR (2021) Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *Int Soil Water Conserv Res* 9: 241–248. https://doi.org/10.1016/j.iswcr.2020.10.007
4. Fahad S, Wang J (2018) Farmers' risk perception, vulnerability, and adaptation to climate change in rural Pakistan. *Land Use Policy* 79: 301–309. https://doi.org/10.1016/j.landusepol.2018.08.018
5. Komarek AM, De Pinto A, Smith VH (2020) A review of types of risks in agriculture: What we know and what we need to know. *Agric Syst* 178: 102738–102747. https://doi.org/10.1016/j.agsy.2019.102738
6. Hardaker JB, Lien G, Anderson JR, et al. (2004) Coping with risk in agriculture, CAB International. https://doi.org/10.1079/9780851998312.0000
7. The World Bank (2016) Agricultural Sector Risk Assessment : Methodological Guidance For Practitioners, Washington DC, World Bank Group.
8. Tudor K, Spaulding A, Roy KD, et al. (2014) An analysis of risk management tools utilized by Illinois farmers. *Agric Financ Rev* 74: 69–86. https://doi.org/10.1108/AFR-09-2012-0044
9. Jankelova N, Masar D, Moricova S (2017) Risk factors in the agriculture sector. *Agric Econ (Czech Republic)* 63: 247–258. https://doi.org/10.17221/212/2016-AGRICECON
10. Gebreegziabher K, Tadesse T (2014) Risk perception and management in smallholder dairy farming in Tigray, Northern Ethiopia. *J Risk Res* 17: 367–381. https://doi.org/10.1080/13669877.2013.815648
11. Akhtar S, LI G cheng, Ullah R, et al. (2018) Factors influencing hybrid maize farmers' risk attitudes and their perceptions in Punjab Province, Pakistan. *J Integr Agric* 17: 1454–1462. https://doi.org/10.1016/S2095-3119(17)61796-9

12. Lebel L, Lebel P (2018) Emotions, attitudes, and appraisal in the management of climate-related risks by fish farmers in Northern Thailand. *J Risk Res* 21: 933–951. https://doi.org/10.1080/13669877.2016.1264450
13. Mgale YJ, Yunxian Y (2021) Price risk perceptions and adoption of management strategies by smallholder rice farmers in Mbeya region, Tanzania. *Cogent Food Agric* 7: 1919370. https://doi.org/10.1080/23311932.2021.1919370
14. Ahmad D, Afzal M, Rauf A (2020) Environmental risks among rice farmers and factors influencing their risk perceptions and attitudes in Punjab, Pakistan. *Environ Sci Pollut Res* 27: 21953–21964. https://doi.org/10.1007/s11356-020-08771-8
15. Iqbal MA, Ping Q, Abid M, et al. (2016) Assessing risk perceptions and attitude among cotton farmers: A case of Punjab province, Pakistan. *Int J Disaster Risk Reduct* 16: 68–74. https://doi.org/10.1016/j.ijdrr.2016.01.009
16. Saqib SE, Ahmad MM, Panezai S, et al. (2016) An empirical assessment of farmers' risk attitudes in flood-prone areas of Pakistan. *Int J Disaster Risk Reduct* 18: 107–114. https://doi.org/10.1016/j.ijdrr.2016.06.007
17. Khan I, Lei H, Shah IA, et al. (2020) Farm households' risk perception, attitude and adaptation strategies in dealing with climate change: Promise and perils from rural Pakistan. *Land Use Policy* 91: 1–11. https://doi.org/10.1016/j.landusepol.2019.104395
18. Huet EK, Adam M, Giller KE, et al. (2020) Diversity in perception and management of farming risks in southern Mali. *Agric Syst* 184: 1–15. https://doi.org/10.1016/j.agsy.2020.102905
19. De Salvo M, Capitello R, Gaudenzi B, et al. (2019) Risk management strategies and residual risk perception in the wine industry: A spatial analysis in Northeast Italy. *Land Use Policy* 83: 47–62. https://doi.org/10.1016/j.landusepol.2019.01.022
20. Sjöberg L, Moen EB, Rundmo T (2004) Explaining risk perception. An evaluation of the psychometric paradigm in risk, Rotunde.
21. Begho T, Daubry TP, Ebuka IA (2022) What do we know about Nigerian farmers' attitudes to uncertainty and risk? A systematic review of the evidence. *Sci Afr* 17: e01309. https://doi.org/10.1016/j.sciaf.2022.e01309
22. Directorate General of Estate Crops (2022) Statistic of National Leading Estate Crops Comodity 2020–2022, Jakarta, Directorate General of Estate Crops, Ministry of Agriculture.
23. Sdoodee S, Rongsawat S (2012) Impact of Climate Change on Smallholders ' Rubber Production in Songkhla Province, Southern Thailand. *Proceeeding of The 2012 International and National Conference For The Sustainable Community Development of "Local Community : The Foundation of Development in the ASEAN Economic Community (AEC)*, 81–86.
24. Hazir MHM, Kadir RA, Gloor E, et al. (2020) Effect of agroclimatic variability on land suitability for cultivating rubber (Hevea brasiliensis) and growth performance assessment in the tropical rainforest climate of Peninsular Malaysia. *Clim Risk Manag* 27: 100203–100221. https://doi.org/10.1016/j.crm.2019.100203
25. Ali MF, Aziz AA, Sulong SH (2020) The role of decision support systems in smallholder rubber production: Applications, limitations and future directions. *Comput Electron Agric* 173: 105442. https://doi.org/10.1016/j.compag.2020.105442
26. Abdulla I, Arshad FM (2017) Exploring relationships between rubber productivity and R & D in Malaysia. *Outlook Agric* 46: 28–35. https://doi.org/10.1177/0030727016689731

27. Qi D, Zhu J, Huang Y, et al. (2021) Factors affecting technology choice behaviour of rubber smallholders: a case study in central Hainan, China. *J Rubber Res* 1–11. https://doi.org/10.1007/s42464-021-00096-6
28. Min S, Waibel H, Cadisch G, et al. (2017) The economics of smallholder rubber farming in a mountainous region of Southwest China: Elevation, ethnicity, and risk. *Mt Res Dev* 37: 281–293. https://doi.org/10.1659/MRD-JOURNAL-D-16-00088.1
29. Jin S, Huang J, Waibel H (2020) Location and economic resilience in rubber farming communities in southwest China. *China Agric Econ Rev* 13: 367–396. https://doi.org/10.1108/CAER-06-2020-0153
30. Goh HH, Tan KL, Khor CY, et al. (2016) Volatility and market risk of rubber price in Malaysia: Pre- and post-global financial crisis. *J Quant Econ* 14: 323–344. https://doi.org/10.1007/s40953-016-0037-4
31. Azis M, Dermoredjo SK, Sayaka B, et al. (2021) Economic perspective of indonesian rubber on agroforestry development, *E3S Web Conf* 305: 02007. https://doi.org/10.1051/e3sconf/202130502007
32. Zaw ZN, Sdoodee S, Lacote R (2017) Performances of low frequency rubber tapping system with rainguard in high rainfall area in Myanmar. *Aust J Crop Sci* 11: 1451–1456. https://doi.org/10.21475/ajcs.17.11.11.pne593
33. Ismail T, Gohet E (2020) Impact of climate change on latex harvesting, *Natural rubber systems and climate change (FTA Working Report)*, 16–18.
34. Rivano F, Maldonado L, Simbaña B, et al. (2015) Suitable rubber growing in Ecuador: An approach to South American leaf blight. *Ind Crops Prod* 66: 262–270. https://doi.org/10.1016/j.indcrop.2014.12.034
35. Olaniyi ON, Szulczyk KR (2022) Estimating the economic impact of the white root rot disease on the Malaysian rubber plantations. *For Policy Econ* 138: 102707. https://doi.org/10.1016/j.forpol.2022.102707
36. Febbiyanti TR, Fairuza Z (2019) Identification of causes of rubber leaves outbreak in Indonesia. *Indones J Nat Rubber Res* 37: 193–206. https://doi.org/10.22302/ppk.jpk.v37i2.616
37. Jin S, Min S, Huang J, et al. (2021) Falling price induced diversification strategies and rural inequality: Evidence of smallholder rubber farmers. *World Dev* 146: 105604. https://doi.org/10.1016/j.worlddev.2021.105604
38. Nicod T, Bathfield B, Bosc PM, et al. (2020) Households' livelihood strategies facing market uncertainties: How did Thai farmers adapt to a rubber price drop? *Agric Syst* 182: 1–11. https://doi.org/10.1016/j.agsy.2020.102846
39. Penot E, Chambon B, Wibawa G (2017) An history of Rubber Agroforestry Systems development in Indonesia and Thailand as alternatives for a sustainable agriculture and income stability, *IRRDB International Rubber Conference*, Bali.
40. Penot E, Thériez M, Michel I, et al. (2022) Agroforestry rubber networks and farmers groups in Phatthalung area in Southern Thailand: A potential for an innovation platform? *For Soc* 6: 503–526. https://doi.org/10.24259/fs.v6i2.12481
41. Ali MF, Akber MA, Smith C, et al. (2021) The dynamics of rubber production in Malaysia: Potential impacts, challenges and proposed interventions. *For Policy Econ* 127: 102449. https://doi.org/10.1016/j.forpol.2021.102449
42. Andriesse E, Tanwattana P (2018) Coping with the end of the commodities boom: Rubber smallholders in Southern Thailand oscillating between near-poverty and middle-class status. *J Dev Soc* 34: 77–102. https://doi.org/10.1177/0169796X17752420

43. Khan NA, Gao Q, Iqbal MA, et al. (2020) Modeling food growers ' perceptions and behavior towards environmental changes and its induced risks : evidence from Pakistan. *Environ Sci Pollut Res* 27: 20292–20308. https://doi.org/10.1007/s11356-020-08341-y
44. Ahmad D, Afzal M, Rauf A (2019) Analysis of wheat farmers' risk perceptions and attitudes : evidence from Punjab, Pakistan. *Nat Hazards* 95: 845–861. https://doi.org/10.1007/s11069-018-3523-5
45. Lebel P, Whangchai N, Chitmanat C, et al. (2015) Climate risk management in river-based tilapia cage culture in northern Thailand. *Int J Clim Chang Strateg Manag* 7: 476–498. https://doi.org/10.1108/IJCCSM-01-2014-0018
46. Alam A, Guttormsen AG (2019) Risk in aquaculture : Farmers' perceptions and management strategies in Bangladesh. *Aquac Econ Manag* 23: 359–381. https://doi.org/10.1080/13657305.2019.1641568
47. Meraner M, Finger R (2017) Risk perceptions, preferences and management strategies: Evidence from a case study using German livestock farmers. *J Risk Res* 22: 110–135. https://doi.org/10.1080/13669877.2017.1351476
48. Bishu KG, O'Reilly S, Lahiff E, et al. (2016) Cattle farmers' perceptions of risk and risk management strategies: Evidence from Northern Ethiopia. *J Risk Res* 21: 579–598. https://doi.org/10.1080/13669877.2016.1223163
49. Thomas G (2018) Risk Management in Agriculture, Scotlandia, The Scottish Parliament.
50. Durrani H, Syed A, Khan A, et al. (2021) Understanding farmers' risk perception to drought vulnerability in Balochistan, Pakistan. *AIMS Agric Food* 6: 82–105. https://doi.org/10.3934/agrfood.2021006
51. Yarong L, Minpeng C (2021) Farmers ' perception on combined climatic and market risks and their adaptive behaviors : a case in Shandong Province. *Environ Dev Sustain* 23: 13042–13061. https://doi.org/10.1007/s10668-020-01198-8
52. Onyeneke RU, Nwajiuba CA, Emenekwe CC, et al. (2019) Climate change adaptation in Nigerian agricultural sector: A systematic review and resilience check of adaptation measures. *AIMS Agric Food* 4: 967–1006. https://doi.org/10.3934/agrfood.2019.4.967
53. He R, Jin J, Kuang F, et al. (2020) Farmers' risk cognition, risk preferences and climate change adaptive behavior: A structural equation modeling approach. *Int J Environ Res Public Health* 17: 85–97. https://doi.org/10.3390/ijerph17010085
54. Huong NTL, Bo YS, Fahad S (2017) Farmers' perception, awareness and adaptation to climate change: evidence from northwest Vietnam. *Int J Clim Chang Strateg Manag* 9: 555–576. https://doi.org/10.1108/IJCCSM-02-2017-0032
55. Iqbal MA, Ping Q, Zafar MU, et al. (2018) Farm risk sources and their mitigation: A case of cotton growers in Punjab. *Pakistan J Agric Sci* 55: 683–690. https://doi.org/10.21162/PAKJAS/18.7070
56. Le TC, Cheong F (2010) Perceptions of risk and risk management in vietnamese catfish farming: An empirical study. *Aquac Econ Manag* 14: 282–314. https://doi.org/10.1080/13657305.2010.526019
57. Hillson D, Murray-webster R (2005) Understanding and Managing Risk Attitude, United States of America.
58. Pindyck RS, Rubinfeld DL (2013) Microeconomics, United States of America, Pearson.
59. Theuvsen L (2013) Risks and Risk Management in Agriculture.

60. Directorate General of Estate Crops (2019) Tree Crop Estate Statistics of Indonesia (Rubber) 2018–2020, Jakarta, Directorate General of Estates Crops Ministry of Agriculture.
61. Winarni B, Lahjie AM, Simarangkir BDAS, et al. (2017) Forest gardens management under traditional ecological knowledge in West Kalimantan, Indonesia. *Biodiversitas* 19: 77–84. https://doi.org/10.13057/biodiv/d190113
62. Statistics of Kalimantan Barat Province (2022) Kalimantan Barat Province in Figures 2022, Pontianak, Statistics of Kalimantan Barat Province.
63. Moser S, Mußhoff O (2017) Comparing the use of risk-influencing production inputs and experimentally measured risk attitude: Do the decisions of indonesian small-scale rubber farmers match? *Ger J Agric Econ* 66: 124–139.
64. Holt CA, Laury SK (2002) Risk aversion and incentive effects. *Am Econ Rev* 92: 1644–1655. https://doi.org/10.1257/000282802762024700
65. Michailova J, Mačiulis A, Tvaronavičienė M (2017) Overconfidence, risk aversion and individual financial decisions in experimental asset markets. *Econ Res* 30: 1119–1131. https://doi.org/10.1080/1331677X.2017.1311234
66. Hosmer DW, Lemeshow S, Sturdivant RX (2013) Applied Logistic Regression., United States of America, Wiley. https://doi.org/10.1002/9781118548387
67. Pedace R (2013) Econometrics For Dummies, United States of America, John Wiley & Sons Inc.
68. Glorya MJ, Nugraha A (2019) Private Sector Initiatives To Boost Productivity of Cocoa, Coffee, and Rubber in Indonesia, Jakarta. https://doi.org/10.35497/291601
69. Ruangsri K, Makkaew K, Sdoodee S (2015) The impact of rainfall fluctuation on days and rubber productivity in Songkhla Province. *Int J Agric Technol* 11: 181–191.
70. Thaochan N, Pornsuriya C, Chairin T, et al. (2020) Roles of systemic fungicide in antifungal activity and induced defense responses in rubber tree (Hevea brasiliensis) against leaf fall disease caused by Neopestalotiopsis cubana. *Physiol Mol Plant Pathol* 111: 101511. https://doi.org/10.1016/j.pmpp.2020.101511
71. Go WZ, Chin KL, H'ng PS, et al. (2021) Virulence of rigidoporus microporus isolates causing white root rot disease on rubber trees (Hevea brasiliensis) in Malaysia. *Plants* 10: 2123. https://doi.org/10.3390/plants10102123
72. Siri-udom S, Suwannarach N, Lumyong S (2017) Applications of volatile compounds acquired from Muscodor heveae against white root rot disease in rubber trees (Hevea brasiliensis Müll. Arg.) and relevant allelopathy effects. *Fungal Biol* 121: 573–581. https://doi.org/10.1016/j.funbio.2017.03.004
73. Syahza A, Backe D, Asmit B (2018) Natural rubber institutional arrangement in efforts to accelerate rural economic development in the province of Riau. *Int J Law Manag* 60: 1509–1521. https://doi.org/10.1108/IJLMA-10-2017-0257
74. Syarifa LF, Agustina DS, Nancy C, et al. (2016) Low Rubber Prices Impact on Socio Economic Condition of Rubber Smallholders in South Sumatera. *Indones J Nat Rubber Res* 34: 119–126.
75. Ullah R, Shivakoti GP, Ali G (2015) Factors effecting farmers' risk attitude and risk perceptions: The case of Khyber Pakhtunkhwa, Pakistan. *Int J Disaster Risk Reduct* 13: 151–157. https://doi.org/10.1016/j.ijdrr.2015.05.005
76. Islam MD Il, Rahman A, Sarker MNI, et al. (2021) Factors influencing rice farmers' risk attitudes and perceptions in bangladesh amid environmental and climatic issues. *Polish J Environ Stud* 30: 177–187. https://doi.org/10.15244/pjoes/120365

77. Sun Y, Han Z (2018) Climate change risk perception in Taiwan: Correlation with individual and societal factors. *Int J Environ Res Public Health* 15: 91. https://doi.org/10.3390/ijerph15010091
78. Rizwan M, Ping Q, Saboor A, et al. (2020) Measuring rice farmers' risk perceptions and attitude: Evidence from Pakistan. *Hum Ecol Risk Assess* 26: 1832–1847. https://doi.org/10.1080/10807039.2019.1602753
79. Fauzi IR, Syarifa LF, Herlinawati E, et al. (2014) Performance of tapping premium system in some rubber plantation enterprises. *Indones J Nat Rubber Res* 32: 157–180. https://doi.org/10.22302/ppk.jpk.v32i2.162
80. Oduro-ofori E, Aboagye Anokye P, Acquaye NEA (2014) Effects of education on the agricultural productivity of farmers in offinso municipality. *Int J Dev Res* 4: 1951–1960.
81. Paltasingh KR, Goyari P (2018) Impact of farmer education on farm productivity under varying technologies: case of paddy growers in India. *Agric Food Econ* 6: 7. https://doi.org/10.1186/s40100-018-0101-9
82. Asadullah MN, Rahman S (2009) Farm productivity and efficiency in rural Bangladesh: The role of education revisited. *Appl Econ* 41: 17–33. https://doi.org/10.1080/00036840601019125
83. Tongkaemkaew U, Chambon B (2018) Rubber plantation labor and labor movements as rubber prices decrease in Southern Thailand. *For Soc* 2: 18–27. https://doi.org/10.24259/fs.v2i1.3641
84. Tanakasempipat P (2019) Reuters, Top rubber producer Thailand hit by fungal disease outbreak. Available from: https://www.reuters.com/article/us-thailand-rubber-idUSKBN1X0118.
85. Razar RM, Hamid NRA, Ghani ZA (2021) GxE effect and stability analyses of selected rubber clones (Hevea brasiliensis) in Malaysia. *J Rubber Res* 24: 475–487. https://doi.org/10.1007/s42464-021-00115-6
86. Ouattara PD, Kouassi E, Egbendéwé AYG, et al. (2019) Risk aversion and land allocation between annual and perennial crops in semisubsistence farming: a stochastic optimization approach. *Agric Econ (United Kingdom)* 50: 329–339. https://doi.org/10.1111/agec.12487
87. Djanibekov U, Villamor GB (2017) Market-based instruments for risk-averse farmers: Rubber agroforest conservation in Jambi Province, Indonesia. *Environ Dev Econ* 22: 133–155. https://doi.org/10.1017/S1355770X16000310
88. Sitepu MH, McKay A, Holt RJ (2019) An approach for the formulation of sustainable replanting policies in the Indonesian natural rubber industry. *J Clean Prod* 241: 118357–118368. https://doi.org/10.1016/j.jclepro.2019.118357
89. Penot E, Ilahang (2021) Rubber Agroforestry Systems (RAS) in West Kalimantan, Indonesia: An historical perspective. *E3S Web Conf* 305: 02001. https://doi.org/10.1051/e3sconf/202130502001