Journal of Infrastructure, Policy and Development 2024, 8(10), 6470.
https://doi.org/10.24294/jipd.v8i10.6470

Article

Enhancing supply chain resilience through risk mitigation strategies: Evidence from smallholder red chili supply chains in East Java Indonesia

Ati Kusmiati[1], **Joni Murti Mulyo Aji**[1,*], **Evita Soliha Hani**[1], **Kacung Hariyono**[2]

[1] Department of Agribusiness, Faculty of Agriculture, Jember University, Jember 68121, Indonesia
[2] Department of Agronomy, Faculty of Agriculture, Jember University, Jember 68121, Indonesia
*** Corresponding author:** Joni Murti Mulyo Aji, joni.faperta@unej.ac.id

CITATION

Kusmiati A, Aji JMM, Hani ES, Hariyono K. (2024). Enhancing supply chain resilience through risk mitigation strategies: Evidence from smallholder red chili supply chains in East Java Indonesia. Journal of Infrastructure, Policy and Development. 8(10): 6470.
https://doi.org/10.24294/jipd.v8i10.6470

ARTICLE INFO

Received: 17 May 2024
Accepted: 26 June 2024
Available online: 23 September 2024

Abstract: The cultivation of red chili in East Java, Indonesia, has significant economic and social impacts, necessitating proactive supply chain measures. This research aimed to identify priority risk agents, develop effective risk mitigation, and enhance supply chain resilience using the SCOR model, House of Risk, Interpretative Structural Modelling (ISM), and synthesis analysis. Examining 238 respondents—including farmers, collectors, wholesalers, retailers, home-agroindustries, and experts—the findings highlight farmers' critical role in supply chain resilience despite risks from crop failures, weather fluctuations, and pest infestations. Simultaneous planting led to market oversupply and price drops, but accurate pricing information facilitated quick market adaptation. Wholesalers influenced pricing dynamics and income levels, impacting farmers directly. To improve resilience, three main strategies were developed through ten key elements: proactive strategies (real-time SCM tracking, Weather Early Warning Systems, risk management team formation, and training), resistance strategies (partnerships, chili stock reserves, storage and drying technologies, GAP implementation, post-harvest management, agricultural insurance, and Fair Profit Sharing Agreements), and recovery and growth strategies (flexible distribution channels and customizable distribution centers). Furthermore, the study delves into the mediating and moderating effects between variables within the model. This research not only addresses a knowledge gap but also provides stakeholders with evidence to consider new strategies to enhance red chili supply resilience.

Keywords: risk factors; risk mitigation; supply chain; resilience; house of risk (HOR); ISM; red chili

1. Introduction

Red chili (*Capsicum annuum L.*) is an economically important vegetable with comparatively rich nutrients (Tang et al., 2023). In addition, red chili is widely used in the food business as a natural colorant and flavoring agent because of its distinctive color, spice, and scent (Taiti et al., 2019). This vegetable is widely grown and consumed as a condiment and spice. Moreover, China, Mexico, Turkey, and Indonesia are the largest producers, collectively accounting for more than 70% of global production (Hernández-Pérez et al., 2020). East Java Province, ranking fifth in Indonesia, contributed an average of 104,832 tons from 2017 to 2021. Jember, Banyuwangi, and Lumajang districts are among the top ten highest red chili-producing districts in the province (Central Bureau of Statistics Indonesia, 2022).

The supply chain of agricultural products is more complex and production centers are widely spread in several regions with small production volumes (Mailena et al., 2021). Meanwhile, the actors in the supply chain management of the commodities include farmers, village intermediaries as well as large traders at the main and district market, retailers, and the chili processing industry. These actors have been mentioned in several research in Indonesia, including West Java Province (Muflikh et al., 2021), Pacet District, Cianjur Regency (Mailena et al., 2021); Yogyakarta (Susanawati et al., 2021), Kulon Progo District, Yogyakarta (Fauzan and Fanestia, 2022). However, the study only sheds light on the flow and performance of the supply chain.

Supply chains within the agriculture sector include uncertainty compared to conventional manufacturing due to factors such as extended, seasonal, and perishable lead times (Behzadi et al., 2017). In addition, the complexity and length pose a vulnerability to risk. Agricultural product supply chain risks become more difficult to manage due to high uncertainty (Mailena et al., 2021). Problems faced by one stakeholder in the supply chain will have an impact on other stakeholders and the entire supply chain (Asrol et al., 2021). When supply chain risks are not controlled, companies will be less likely to fail to deliver on their clients' promises (Keswani and Vlachos, 2022). Effective risk management can reduce financial losses caused by fluctuations in demand and unexpected market dynamics, thereby increasing supply chain resilience. Thus, the supply chain remains efficient and adaptive to various changes.

Several studies related to the relationship between Risk Management and chain resilience have been conducted by Kumar (2024) and Keswani and Vlachos (2022) using a literature review, but there is no empirical evidence of agricultural products that are highly susceptible to supply chain disruptions. Empirical evidence related to the relationship between supply chain risk and supply chain resilience of manufacturing companies has been presented by Um and Han (2020). However, the study examined the entire manufacturing company even though the risks of each company are different, especially agricultural products that have more risks. The study did not examine supply providers from upstream businesses. Risk mitigation of chili peppers has been carried out by Dewi et al. (2023) but agroindustry actors have not been researched in the study. Nevertheless, the discussion of risk mitigation is only to improve supply chain management which employs FMEA analysis, augmented by a HOR analysis to enhance its effectiveness. Nyoman Pujawan and Geraldin (2009) said that FMEA tends to be more reactive because of the focus on identifying and mitigating failure modes after they have occurred or are anticipated. Meanwhile, HOR encourages a more proactive approach to risk management by focusing on identifying and eliminating the causes of risks before they result in failure mode.

Specific integrated plans at each level of the red chili supply chain have not been extensively explored even though previous research has examined agricultural commodity supply chain strategies to mitigate risks (Andayani et al., 2020; Dewi and Dewi, 2017; Fauzan and Fanestia, 2022; Harniati et al., 2022; Mailena et al., 2021; Susanawati and Hida, 2023). The earlier risk mitigation research was only conducted in one district, despite the inclusion of inter-regency actors. Only a few researchers have conducted risk analyses and implemented mitigations for all actors, including farmers, traders, and agroindustries. Risk mitigation that has been done before primarily focuses on improving supply chain management. Meanwhile, supply chain resilience is more focused because of a specific disruption. Few studies in agriculture include empirical evidence that comprehensively integrates risk management and supply chain resilience within a holistic framework. This research was conducted to address this gap. Therefore, this study aims to Identify priority risk agents, develop effective risk mitigation, and improve supply chain resilience for all supply chain actors in East Java province. This research contributes to the development of a comprehensive framework for effectively understanding risk management to enhance the resilience of the red chili supply chain, which is not found in most recent studies. The comprehensive integration of risk mitigation is considered across a broader area and the analysis serves as a reference for other tropical developing countries in preparing risk mitigation and supply chain resilience strategies.

2. Literature review

2.1. Supply chain risk

Supply chain risk refers to the instability of the entire supply chain system due to adverse factors such as external environmental changes and cooperative management vulnerabilities. As companies become closer, problems in each supply chain significantly impact the entire chain, with supply or demand disruptions being the primary cause of failures (Dai and Liu, 2020).

Stone and Rahimifard (2018) and Leat and Revoredo-Giha both explained that supply chain risks include political risks (conflicts, export restrictions, regulatory costs, weak infrastructure maintenance), social risks (population growth, social unrest, food fraud, crime, industrial action), economic risks (financial fluctuations, food inflation, energy price instability), and environmental risks (territory, geology, biology, climate disruption). Abrudan et al. (2022) added that supply chain risks also encompass supply risks, shipping risks, and manufacturing process risks, which are often the result of environmental uncertainty.

Chain risk comes from the source of risk, manufacturing risk, and shipping risk (Um and Han, 2020). These risks can be external or internal, originating from suppliers and customers (Brusset and Teller, 2017). Sources of risk include supply risks, price risks, production risks, quality risks, environmental risks, and transportation risks (Wahyuningtyas et al., 2021). Risks have various forms and forms, so they need to be studied, for example, based on their origin (e.g., whether the risk is supply or demand-based) or their type (e.g., environmental, social, political) (Choudhary et al., 2022). They can stem from suppliers (raw material risks, intellectual property, delivery time), producers (production disruptions, loss of core competencies), demand (acceptance and reputation), logistics (delivery time, cargo damage), information (lack of information, information infrastructure, company information systems), and environmental factors (operational and increased production costs) (Nguyen et al., 2021).

Agriculture is a high-risk industry due to natural disasters and market risks. Production risks arise from adverse weather conditions like drought, freezing, or excessive rainfall, and damage from insects, pests, and diseases. Market risk is primarily due to price fluctuations or demand (Gu and Wang, 2020). Additionally, farming risks stem from the physical and operational environment and competitors

(Dewi and Dewi, 2017). Food supply chain risks include natural disasters, workers' strikes, changes in government regulations or safety standards, rapid raw material deterioration, seasonality, food safety incidents, fraud, market and pricing strategies, and economic crises (Kuizinaitė et al., 2023).

Risk management in supply chains, facilitated by Supply Chain Risk Management (SCRM), includes several key stages: risk identification, assessment, mitigation, and recovery or resilience (Ho et al., 2015). Risk identification entails recognizing events or activities with potential negative impacts on supply chain performance. Risk assessment involves analyzing these risks based on stakeholder needs and company objectives. Subsequently, risk mitigation deploys resources systematically to address these identified risks. Even if risks cannot be fully mitigated, these plans aid in recovery, thereby enhancing resilience (Choudhary et al., 2022). Risk management in supply chains relies on specialized tools to manage risks effectively. Its primary goal is to identify and minimize potential risks across the supply chain through coordinated stakeholder efforts. This approach involves designing mitigation strategies, minimizing costs, reducing organizational vulnerability, and enhancing overall supply chain conditions (Asrol et al., 2021).

2.2. Supply chain resilience (SCRES)

Supply chain resilience refers to the operational capability enabling disrupted supply chains to recover and strengthen (Brusset and Teller, 2017). It involves flexibility, allowing shippers to switch distribution channels without losing continuity or output (Chenarides et al., 2020). Supply Chain Resilience, as defined by Hosseini et al. (2019), utilizes absorptive capacity to resist disruptions, adaptive capacity to minimize their impacts, and restorative capacity to return to normal operations efficiently. Béné (2020) emphasizes its role in enabling organizations, supply chains, or systems to respond effectively to disruptions and uncertainties.

Pettit et al. (2019) emphasize that supply chain resilience complements rather than replaces risk management. Resilience analysis should encompass not only a company's self-assessment but also the evaluation of its suppliers, customers, and reverse logistics channels across the entire supply chain. Stone and Rahimifard (2018) define agricultural supply chain resilience as stakeholders' collective ability to ensure a stable food supply through accurate anticipation of disruptions and strategies that delay impacts, aid rapid recovery, and enable cumulative learning post-disruption. According to Coopmans et al. (2021), resilience reflects the system's capacity to anticipate, survive, or adapt to challenges, with stressful times offering opportunities to identify key contributors to agri-food system resilience. Nguyen et al. (2021) assert that companies must react and adapt swiftly to both known and unknown risks. The ability of a supply chain to survive, adapt, and prosper is synonymous with supply chain resilience.

Zhao et al. (2017) outlined key resilience factors in the agri-food supply chain: traceability, inter-organizational knowledge management, supply chain collaboration, risk management, cultural aspects, and agility. Soni et al. (2014), identified elements crucial for supply chain resilience, including agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture, adaptive capabilities, and supply chain structure.

Singh et al. (2019) identified seventeen indicators for supply chain resilience, forming a framework to help managers detect and manage disruptions. These indicators include agility, flexibility, redundancy, visibility, collaboration, sustainability, sensitivity, risk management culture, speed, market participation, risk control, public-private partnerships, adaptability, network design, and security.

The supply chain resilience phase goes through three phases, namely preparing, responding, and recovering (Hendry et al., 2019). More broadly, the supply chain resilience concept map shows three phases, namely the pre (proactive), during (concurrent) and post-(reactive) strategy phases (Ali et al., 2017). There are three phases and aspects of supply chain resilience, namely phase one before the disruption, the second phase during the disruption, and the third phase after the disruption. Phase 1: Capability, anticipation, and Preparedness. Phase 2: Adaptability, Response, Time, Phase 3: Recovery, original and financial performance (Simbizi et al., 2021).

Hohenstein et al. (2015) described the SCRES phases as readiness (preparing to avoid threats), response (managing uncertain and volatile conditions), and recovery (returning to the original state). Blessley and Mudambi (2022) proposed strategies across three stages: strategic anticipation, adaptation and response, and recovery and learning, aiming to enhance supply chain resilience. Ali et al. (2017) and Singh et al. (2019) divided the SCRES strategy into four stages: (1) readiness, (2) response, (3) recovery, and (4) adaptation. Supply chain resilience is divided based on ex-ante and post-ante disruptions.

The strategies proposed in each phase are Proactive Strategy (aligned with the Readiness phase) and Reactive, Responsive, and Adaptive Strategy (Stone and Rahimifard, 2018). Anticipation phase (visibility, awareness, security, sustainability, Supply Chain Risk Management), resistance phase (Flexibility, redundancy, collaboration, Supply Chain Network, Revenue Sharing, Robustness), Response and Recovery (Velocity, Agility, Public-private partnership, adaptability, market position, and information sharing (Singh et al., 2019). Structurally, there are 3 dimensions of resilience with capabilities in each dimension, namely readiness (awareness, visibility, redundancy), response (agility, flexibility, collaboration), and recovery (contingency planning and market position) (Han et al., 2020). Supply chain strategies to minimize the impact of supply chain disruptions include (1) supply chain collaboration (2) coordination between stakeholders, (3) information sharing, (4) process digitization, (5) sharing resources such as finance, human resources, technology, etc., most of which are interrelated with each other (Kumar and Kumar Singh, 2021).

3. Materials and methods

3.1. Research Method

This study used the analytical descriptive analysis method. A descriptive approach was used to describe the condition of the supply chain based on the Supply Chain Operations Reference (SCOR) approach in each institution. Furthermore, analytical analysis was applied to measure the severity and occurrenceance of a risk,

risk agent, risk event, risk mitigation, and structural model of resilience Through a combination of descriptive and analytic approaches, it would provide in-depth insights that can be used to compile risk mitigation so that it could improve the resilience of the red chili supply chain.

3.2. Research location, data collection, and sampling method

The selection of research sites was carried out purposively, in three specific districts namely, Jember, Lumajang, and Banyuwangi. The locations were chosen due to their significant contribution to red chili production within East Java Province. The data collection involved questionnaire-guided closed-ended structured interviews. Farmer respondents were initially selected purposively from the most well-known and active farmer groups across three districts. Subsequently, other supply chain actors were identified using snowball random sampling. Farmers were asked to recommend other participants involved in the red chili supply chain, including collectors, wholesalers, and retailers. This process continued iteratively with each new recommended respondent until a sufficient number of respondents was reached or no more relevant recommendations were available. Agroindustries were deliberately chosen, as researchers identified only three small agroindustries in two districts. 218 respondents participated in this research as presented in **Table 1**.

Table 1. The number of research respondents in three districts.

Respondents	Jember	Banyuwangi	Lumajang
Farmer	55	60	60
Collectors	6	5	6
Wholesalers	3	3	3
Retailers	5	4	5
Agroindustry	2	1	-
Total	71	73	74

Source: Primary data elaboration (2024).

The respondents to develop a structural model of supply chain resilience were deliberately chosen using a purposive method. They included three Heads of the Horticulture Division from the Agriculture Office in three districts, three Field Extension Officers (PPL), two Agricultural Product Quality Supervisors, three heads of farmer groups, three wholesalers, two collectors, the Chairman of the Indonesian Chili Agribusiness Association (AACI) East Java Region, the Chairman of a Sustainable Cooperative in Lumajang Regency, and one academic from the University of Jember. These respondents were selected because they represent key institutions involved in the red chili supply chain in East Java province, such as farmer groups, collectors, wholesalers, and cooperatives. Additionally, interviews were conducted with formal institutions supporting the large red chili supply chain, such as the Agriculture Office, Field Extension Officers (PPL), and the Chili Association, as well as obtaining expert opinions from a university academic. In total, there were 20 respondents.

3.3. Analysis methods

This research uses Supply Chain Operations Reference (SCOR) and HOR (House of Risk) analysis. Guhathakurta (2022) and Teniwut et al., (2020) explained that SCOR was a valuable tool for understanding and improving supply chain operations. The model consists of five main processes, namely plan, source, make, deliver, and return. Meanwhile, House of Risk (HOR) is useful for developing management that focuses on preventive measures to mitigate risks and there are two phases in the analysis (Nyoman Pujawan and Geraldin, 2009). HOR 1 commences with identifying risk events (RE) by assessing severity on a scale of 1 to 10. Additionally, the determination of risk agents (RA) or sources of events is measured by a scale of 1 to 10, where the higher the scale, the greater the chance of risk agents. The relationship between risk and the agent is assessed with the numbers 0, 1, 3, and 9, representing zero, low, medium, and good correlation, respectively. The value of the Aggregate Risk Potential of the Risk Agent (*ARP*) is determined by:

$$ARPj = Oj \sum Si\ Rij \tag{1}$$

Oj describes the event score of the risk agent, *Si* is the severity, and *Rij* signifies the correlation between *j* and *i*. Risk sources should be arranged according to *ARP* value by selecting the agent with the highest frequency. Subsequently, the Pareto law must be applied to select priority risk agents. Risks with a cumulative *ARP* below 80% are sources of priority risks addressed in supply chain risks.

Risk management, or Stage HOR 2, decides on a suitable plan for turning away possible agents. Based on *ARP* in HOR 1, this step commences with selecting a few risk agents with the highest priority. The best preventive action (*P*) or mitigation method is selected to remove possible risk agents. The mitigating measure can be applied to one or more risk agents. An assessment score of 0, 1, 3, or 9 is used to determine the association between each mitigation action (*P*) and the cause of risk (*A*). Subsequently, the computation of each strategy's total effectiveness value (*TEk*) is considered by applying the following formula.

$$TEk = \sum iARPjEjk \tag{2}$$

The connection between each strategy and the risk agent is indicated by *Ejk* and the Effectiveness to Difficulty (*ETD*) is calculated using the following formula.

$$ETDk = TEk/Dk \tag{3}$$

The level of difficulty of action (*Dk*) was assessed using 3, 4, and 5 scales, denoting acts that are simple to perform, quite challenging, and extremely difficult to implement. Various priority ratings are selected based on each risk strategy action (*Rk*), sorted by *ETD*. Mitigation actions with the highest *ETD* are priority strategies requiring further attention to prevent the development of risk agents using the Pareto law.

Other risk analysis tools that can be used are FMEA and Fuzzy AHP. Failure mode and effects analysis (FMEA) is a widely used reliability analysis tool for identifying and eliminating known or potential failures in the system, design, and process (Wang et al., 2018). Fuzzy AHP is a decision-making method that combines the principles of the Analytic Hierarchy Process (AHP) with fuzzy set theory to handle uncertainty and subjectivity in the decision-making process (Liu et al., 2020). This study used HOR compared to FMEA and Fuzzy AHP because HOR focuses on identifying risk agents and developing mitigation strategies to reduce or eliminate these risks. It provides a more direct and practical approach to handling risk. FMEA tends to focus more on failure mode analysis and its impact, rather than on identifying the overall cause of risk. Fuzzy AHP focuses more on prioritizing risk criteria and subcriteria, which can become too abstract and not direct toward mitigation solutions.

The strategy to increase the resilience of the red chili supply chain used Interpretative Structural Modelling (ISM) analysis. ISM analysis was used to analyze each element of the resilience of the red chili supply chain and to explain the conceptual relationships that occur between elements as well as to determine the level of sub-element hierarchy in each element. The initial step was to outline each element and establish the relationships between them. This relationship was assessed using symbols, namely V, A, X, O. The meaning of the symbol was:

V: The *i*-th element affects the *j*-th element, but the *j*-th element did not affect the *i*-th element.

A: The *j*-th element affects the *i*-th element, but the *i*-th element did not affect the *j*-th element.

X: The *i*-th and *j*-th elements influence each other.

O: The *i*-th and *j*-th elements do not affect each other.

Next, compile the Structural Self Interaction Matrix (SSIM) and Reacibility Matrix (RM). RM was compiled from the result of an SSIM matrix converted to a binary number. The conversions were as follows;

1) If the relationship of element (*i*, *j*) = V, then the value RM (*i*, *j*) = 1 and (*j*, *i*) = 0
2) If the relationship of elements (*i*, *j*) = A, then the values RM (*i*, *j*) = 0 and (*j*, *i*) = 1
3) If the relationship of elements (*i*, *j*) = X, then the values RM (*i*, *j*) = 1 and (*j*, *i*) = 1
4) If the relationship of elements (*i*, *j*) = O, then the values RM (*i*, *j*) = 0 and (*j*, *i*) = 0

Next, test the Reachability Matrix (RM) using transitivity rules. Classify elements and create structural models. The classification of sub-elements was based on the results of the final Reachability Matrix, i.e., those that have met the transivity rules. The result of the Dependence value is used to determine the number of levels available, while the Driver Power value is used to determine the rank value to determine the hierarchy level of each element.

4. Results

4.1. Risk identification

SCOR activities carried out by red chili supply chain actors in East Java Province are reported in **Table 2**. This table consists of the plan, source, make, deliver, and return implemented by the supply chain actors. The activities in the five stages of SCOR demonstrate the linkages between supply chain actors. The activities lead to risk events (RE) and risk agents (RA). Results from the three districts show 14 RE and 18 RA, 13 RE and 12 RA, 16 RE and 17 RA, 14 RE and 13 RA, as well as 16 RE and 18 RA at the farmer, wholesaler, collector, retailer, and agroindustry levels, respectively. Farmers face RE and agents with the highest severity and occurrence score (value = 10) compared to other actors (**Table 3**).

Table 2. Identification of red chili supply chain activities in East Java Province.

SCOR Process	**Supply Chain Activities**		
	Farmers	**Collectors/Wholesalers/Retailers**	**Agroindustry**
Plan	● Production and harvesting planning	● Cost planning for the purchase and shipping cost planning	
	● Capital and marketing planning	● Labor requirement planning	
Source	● Procurement of inputs, production facilities, and labor	● Receiving commodities from farmers and Procurement of capital to farmers	● Receipt of raw materials, storage, consumers demand
Make	● Raising process of red chili	● Purchase of red chili	● Processing of dried chili powder and oil chili
	● Hharvesting process of red chili	● Sorting, sales, and payment	
Delivery	● Delivery of commodities to the next marketing institution		● Delivery of processed red chili to consumers
Return	● Not returned but was given a different price	● Not returned but given a different price or reduced weight	● Raw material return

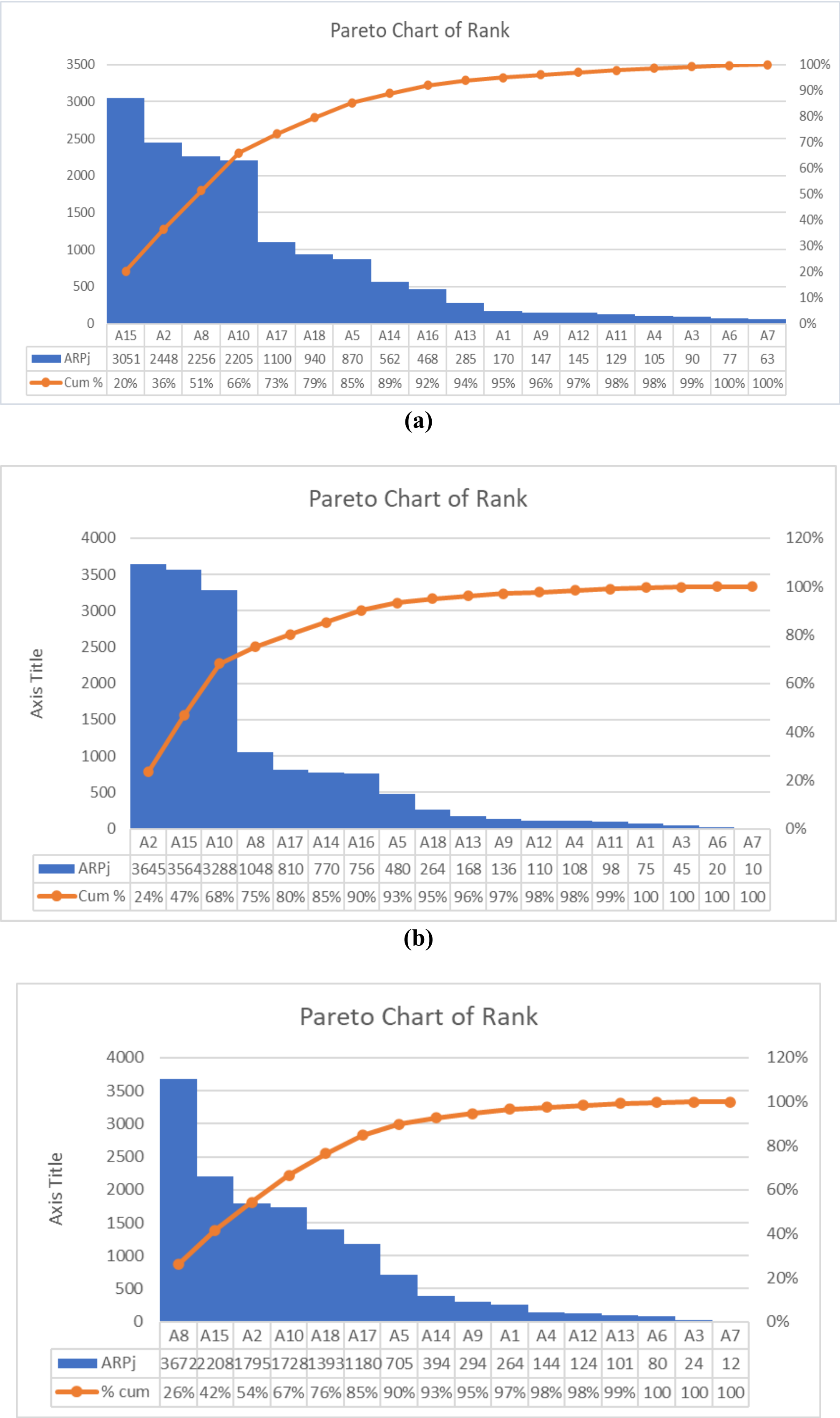
Source: Primary data elaboration, 2024.

Table 3. The highest severity (S) and occurrence (O) for farmers in the three districts of East Java Province.

Risk Event	**District**	**Description**	**Risk Agent**	**District**	**Description**
E2	Jember	Difficulty in obtaining capital	A17	Jember, Banyuwangi Lumajang	Farmers' bargaining power is weak
E8	Jember	Plants are susceptible to pests and diseases			
E11	Jember	The number of harvests does not meet the target	A5	Banyuwangi	Instability in the supply of red chili
E12	Jember	Farmers cannot set prices			
E4	Banyuwangi	Volatile prices			
E5	Banyuwangi	Limited procurement of production facilities			
E10	Banyuwangi	Defective and damaged Red chili s during harvest			
E11	Banyuwangi	The harvest amount is not on target			
E5	Lumajang	Limited procurement of production facilities			
E8	Lumajang	Plants are susceptible to pests and diseases			

Source: Primary data elaboration, 2024.

Based on ARP value in HOR 1, Pareto diagrams are created for each actor in the red chili supply chains (**Figure 1a–c**). ARP value was used to identify and prioritize the most significant risk agents to be handled first. The highest ARP value indicated that the risk agent should get the priority for mitigation. In this context, the Pareto diagram shows 4 to 9 risk agent priorities but some did not need attention. According to the HOR 1 analysis, the priority risk agent of farmers in Jember, Banyuwangi, and Lumajang Districts is the plant attacked by pests and diseases (A15, *ARPj* value of 3.051), weather and climate uncertainty (A2, *ARPj* value of 3645), as well as high planting and maintenance capital (A8, *ARPj* value of 3672), respectively.



(a)

(b)

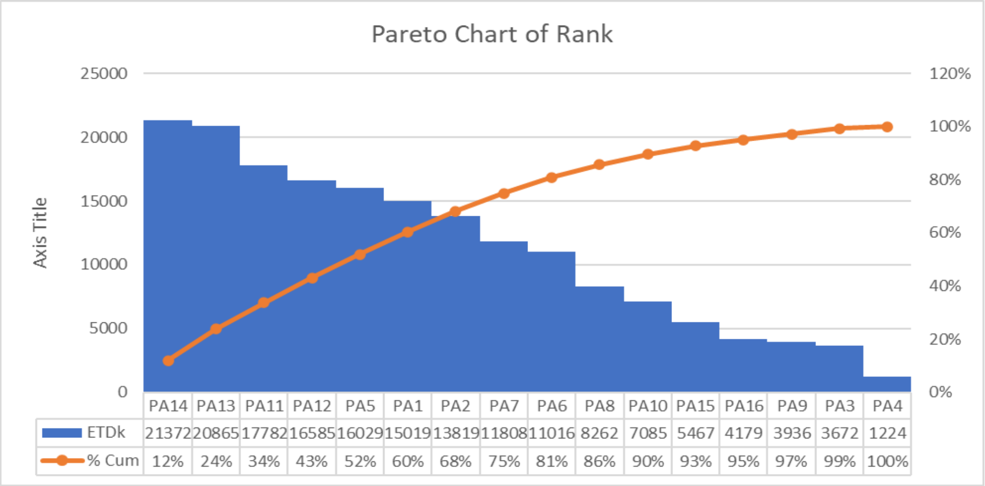
(c)

Figure 1. Pareto Diagram HOR I Farmer **(a)** Jember; **(b)** Lumajang; and **(c)** Banyuwangi.

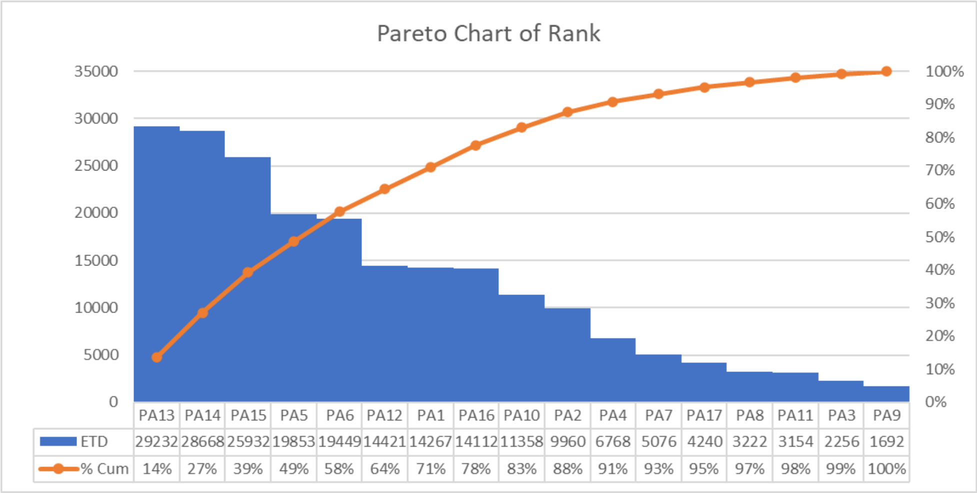
Source: Primary data elaboration (2024.)

4.2. Risk mitigation of the red chili supply chain in three districts of East Java Province

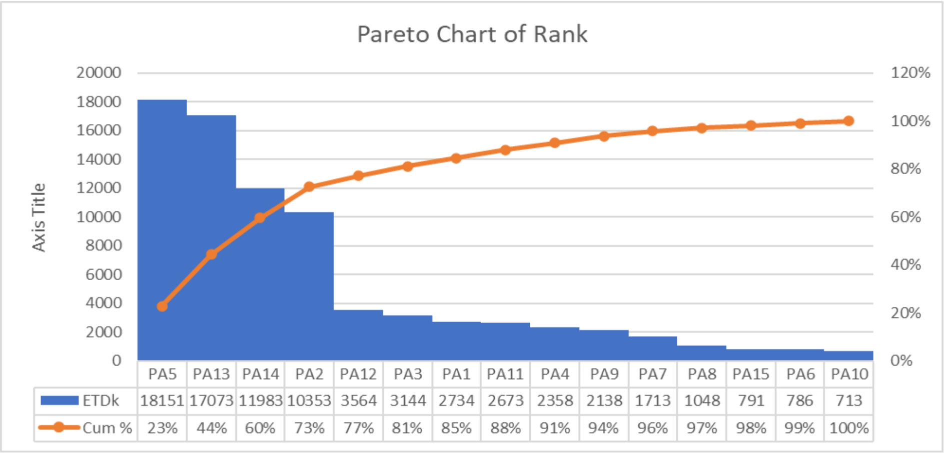
Risk mitigation is carried out in the form of determining strategies using HOR 2 after the priority agent is determined. HOR 2 calculates *ETDk* to determine the risk mitigation and Pareto diagrams are created for each actor in the red chili supply chain **(Figure 2a–c**). Each Pareto diagram shows 4 to 9 risk mitigation priorities but some do not need attention. According to the analysis results, the main priority of risk mitigation strategies for farmers in Jember, Banyuwangi, and Lumajang Districts is to carry out periodic controlling and evaluation of chili cultivation (PA13, *ETDk* a number of 29,332), conduct intensive planting and maintenance of red Red chili (PA5, *ETDk* number of 18,151), as well as check and perform regular maintenance (PA14, *ETDk* number of 21,372), respectively.



(a)



(b)



(c)

Figure 2. Pareto diagram HOR 2 Farmer in **(a)** Jember; **(b)** Lumajang; and **(c)** Banyuwangi.

Source: Own elaboration (2024).

4.3. Supply chain resilience elements

Based on the results of the Final Reachability Matrix (RM) in **Table 4**, the Dependence value is used to determine the number of existing levels, it can be seen that the largest number L is 4, meaning there are four levels in the structural

Table 4. Reachability Matrix (RM) final element of resilience.

Ej **Ei**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**	**A13**	**A14**	**A15**	**A16**	**A17**	**DP**	**R**
Visibility (A1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Situation Awareness (A2)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16	2
Security (A3)	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	15	3
Sustainilibilty (A4)	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	3
Risk Management Culture (A5)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Flexibility (A6)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Redundancy (A7)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Collaboration (A8)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Robustness (A9)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Agility (A10)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Velocity (A11)	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	16	2
Market Position (A12)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Adaptability (A13)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Information Sharing (A14)	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	15	3
Risk and Income sharing (A15)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	1
Knowledge (A16)	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	13	4
Trust (A17)	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	16	2
D	15	16	16	14	17	17	15	17	16	17	16	17	16	16	17	17	17		
L	3	2	2	4	1	1	3	1	2	1	2	1	2	2	1	1	1		

Source: Primary data elaboration (2024).

resilience model, while the Driver Power value is used to determine the rank value to determine the level of hierarchy of each sub-element. Each element is already distributed at Hierarchy Levels 1 to 4.

5. Discussion

Each district has different risk agent priorities and mitigation in each supply chain actor, as shown in **Table 5**.

Table 5. ARP priority risk agent value and ETDk risk mitigation value in East Java Province.

Risk Agent	**ARP Value**			**Risk Mitigation**	**ETDk Value**		
	Jbr	**Bwi**	**Lmj**		**Jbr**	**Bwi**	**Lmj**
Farmer				**Farmer**			
The plant is attacked by pests and diseases	3051*	3564	2208	Carry out control and evaluation of farm workers during chili cultivation periodically	29,332*	17,073	16,585
Weather and climate uncertainty	2448	3645*	1795	Conduct intensive planting and maintenance of red chili	19,449	18,151*	16,029
High planting and maintenance capital	2256	1048	3672*	Inspect and control pests and diseases regularly and appropriately	25,932		21,372*
Collector				**Collector**			
Farmers do not follow sales and loan agreements	335*	444	1332*	Establish broad partnerships with other farmers		3423*	
Red chili is damaged and not according to market standards	216	792*	1200	Improve communication with related institutions	3180*		9132*
Wholesaler				**Wholesaler**			
The harvest season of red chili concurrently at the same time (oversupply)	1519*		465	Update market price information	11,746*	2407	
Red chili is damaged and not according to market standards		580	972*	Controlling human resources		2697*	7,560
Farmers do not follow sales and loan agreements	624	696*	685	Improve communication with suppliers	4318	990	11,688*
Retailer				**Retailer**			
The instability of the amount of supply in the market	285*		403	Communicate with related supply chain actors	3368*		2484*
Weather and climate uncertainty	270	846*		Re-sort at the retailer level		25,957*	828
Red chili is damaged and not according to market standards	192	813	841*				
Agroindustry				**Agroindustry**			
The lack of supply of dry red chili	1840*	498		Develop new methods of post-harvest storage and handling	8493*		
Weather and climate uncertainty	1044	792*		Communicate with relevant supply chain actors	8055	3921	

*Highest priority risk sources in each district.
Note: Jbr = Jember; Bwi = Banyuwangi; Lmj = Lumajang.
Source: Primary data elaboration (2024).

1) Actor Risk Agents

Farmers are the primary producers of red chili peppers and are responsible for cultivation. They determine the quality and quantity of red chili produced, as well as conducting initial post-harvest handling before selling to collectors. Farmers face the greatest risk within the supply chain, as evidenced by the highest ARP value among all actors. The most pressing risk agent is high capital, particularly in Lumajang Regency (*ARP* = 3672). This means that capital risk is the most important risk agent to be immediately mitigated. Not all farmers in East Java Province have sufficient capital. The availability of adequate capital for red chili cultivation greatly influences farmers' decisions to continue cultivating red chili. These findings further support the idea of Suryani et al. (2023), who identified limited capital as a priority risk agent, and De and Pohit (2021), who stated that small farmers struggled with capital, affecting their ability to cover production costs. The results of the study show that with higher capital, farmers can sustainably produce red chili, thereby strengthening the resilience of the red chili supply chain. Farmers can buy quality inputs and more modern technology with sufficient capital. However, many farmers fail to harvest and are subsequently unable to replant red chili, leading them to switch to planting other commodities that require less capital. This finding is in agreement with (Agyekumhene et al., 2018) findings which showed that a lack of capital leads to limited production, and (Mahbubi et al., 2024) who noted that the cultivation capital of agricultural commodities is increasing because fluctuations in the price of inputs (seeds and fertilizers) tend to increase. In addition, Lu et al. (2024) mentioned that insufficient capital limited advancements in planting technology.

Other findings show that the risk agent that must be immediately addressed by farmers, retailers, and agroindustry traders is weather uncertainty. Rahman et al. (2022) stated that the impact of climate change on agricultural systems was not only on farmers but also on other levels along the supply chain. In East Java Province, Weather uncertainty leads to unpredictable red chili planting schedules, resulting in inconsistent red chili production and an unstable supply of red chili to the market. This aligns with the findings of Andayani et al. (2020), Dewi and Dewi (2017), Gu and Wang (2020), Suryani et al. (2023), who identified climate change and erratic weather as priority risk agents. Banyuwangi Regency has the highest *ARP* value (*ARP* = 3645) because farmers in that area plant year-round, they frequently encounter weather uncertainty attributed to global climate change. The *ARP* value highlights climate change as the second-priority risk agent requiring immediate attention. Climate change poses challenges for farmers in adapting, leading to unstable production. Consequently, this instability affects sales activities among retailers and in the chili agroindustry, resulting in reduced revenue from red chili. The present findings seem to be consistent with other research which found climate change significantly reduces red chili productivity through increased droughts as well as pest and disease prevalence, impacting the profits of farmers and traders (Djomo et al., 2020; Ebert, 2017; Bhutia et al., 2018; Tang et al., 2023). The decrease in production has resulted in an unstable supply of red chili, thus disrupting the resilience of the supply chain.

The third priority significant risk agents that need to be found to mitigate risk were pest and plant disease attacks, with the highest *ARP* value reported in Jember (*ARP* = 3051) due to the high severity and frequency of this incident. Pests and diseases significantly affect red chili production, leading to total crop failure (Ahmad Loti et al., 2020; Nasruddin et al., 2020). Controlled pests can contaminate stored crops and threaten farmers' income (Andayani et al., 2020; Dewi and Dewi, 2017;

Gu and Wang, 2020). These various studies were the same as those experienced by farmers in the research area. The variability in types of pests and diseases affecting chili plants from one season to another poses a challenge for farmers struggling to adequately tend to crops. Consequently, crop failures are frequently experienced, leading to disruptions in the supply chain. Increased incidences of pests and diseases invariably result in diminished production, thereby contributing to a reduction in supply. In this context, the resilience of the red chili supply chain becomes increasingly difficult to sustain.

The traders involved in the red chili supply chain include collectors, wholesalers, and retailers. Collectors purchase red chili from farmers in bulk, temporarily store it, sort it, and then sell it to wholesalers. Wholesalers buy large quantities of red chili either from collectors or directly from farmers and distribute them to various markets, such as intercity wholesale markets and local retailers in each district. They play a crucial role in supply chain management, handling logistics, storage, and distribution of chili peppers across different regions in Indonesia. Wholesalers also influence supply and price stability. Retailers sell red chili directly to end consumers through traditional markets or grocery stores, ensuring the availability of fresh and high-quality chili for consumers.

For traders, the primary concern lies in the potential default of farmers on capital loans due to crop failures, which complicates the rotation and threatens the sustainability of businesses. In response, some prefer to secure bank loans to maintain operations, while others may face the possibility of closure. This causes the supply to be affected and the resilience of the chili supply chain to decrease. Defaults are common among smallholders in developing countries, particularly following catastrophic events or economic downturns, such as the COVID-19 pandemic (Mahbubi et al., 2024; Savitha and Kumar, 2016; Smith, 2016; Saitone et al., 2018; Suryani et al., 2023; Lu et al., 2024). Additionally, the failure to adhere to agreements to sell crops to specific traders disrupts the supply chain since farmers may sell to others offering higher prices. The dynamics weaken bargaining power and can trap farmers in exploitative contracts (Al Zarliani et al., 2023; Chitra et al., 2023; Hung and Khai, 2020; Ibikoule et al., 2024; Núñez et al., 2016; Rahman et al., 2022). Several previous studies conducted in various countries, including the findings of this study, indicate that smallholder farmers frequently face defaults, particularly when crops fail, prices plummet, and unforeseen conditions prevent them from repaying loans. The perishable nature of red chili poses risks to collectors, wholesalers, and retailers when it deviates from market standards. Farmers often neglect sorting the crops, resulting in diminished quality, supply instability, and price fluctuations. These factors undermine supply chain resilience, exacerbated by extended intercity delivery times and reduced trader income. Other research corroborates the findings of this study, noting the decline in quality, quantity, color, and firmness of red chili during marketing, as well as the absence of viable storage strategies for perishable products (Djomo et al., 2020; Fernández-González et al., 2022; Hung and Khai, 2020; Krishna et al., 2024; Munarso et al., 2020; Ul Hasan et al., 2021).

Wholesalers in East Java province face the immediate challenge of the simultaneous harvest of chili leading to oversupply. This issue is particularly prevalent in Jember Regency, where chili planting occurs simultaneously. Conversely, Banyuwangi Regency avoids this risk since farmers plant chili throughout the year across different plots of land. The resultant oversupply drives down the price, leading to significant wastage and financial losses for all stakeholders. In this context, achieving resilience in the supply chain becomes increasingly difficult. The observation was consistent with (Dewi and Dewi, 2017), where abundant production capacity posed the greatest risk to farmers. Spiker et al. (2023) and Zhang and Cheng (2023) reported the effects of a strained supply chain on agricultural oversupply events. According to previous research, oversupply events strain supply chains, leading to waste, falling domestic prices, financial difficulties, and reduced market pressure (Abrudan et al., 2022; Esteso et al., 2021; Luo et al., 2022; Wegren, 2018).

The agroindustry processes chili into value-added products such as dried chili powder, chili oil, and chili sauce. They set quality standards that meet the desires of consumers. The agroindustry plays a pivotal role in innovating new products and developing more efficient processing technologies. The types of processed red chili products in small agroindustries differ from those in large agroindustries, which primarily mass-produce chili sauce. Home agroindustries that produce chili powder and oil face the primary risk of inadequate dried chili crop supply. The agroindustry dries fresh chili under the sun, extending the time of the production process. In Malaysia, traditional sun-drying methods are commonly used to dry the crop (Fudholi et al., 2013). The knowledge of home agroindustry causes the drying method in the research area to be very simple. Meanwhile, the results of Deng et al. (2017) showed that there were various drying techniques that were more effective and efficient. Limited availability of dried chili directly impacts production volumes and sales, threatening the resilience of the supply chain.

2) Supply Chain Risk Mitigations

At the farmer level, increasing the resilience of the red chili supply chain can be achieved by formulating and prioritizing risk mitigation strategies. **Table 4** shows the risk mitigation priorities to be implemented by each supply chain actor. Farmers can mitigate risks by controlling and evaluating farm workers (*ETDK* value = 29,332), practicing intensive red chili cultivation (*ETDK* value = 21,372), as well as regularly monitoring for pests and plant diseases (*ETDK* value = 18,151). The ETDK value indicates that these three activities were risk mitigation priorities that must be implemented immediately in the three districts. Strategies to support risk mitigation include intensive cultivation adhering to Good Agricultural Practices (GAP) to ensure sustainable production. Pest and disease management should be integrated and environmentally friendly, as excessive use of chemicals has been common, leading to high yields. Farm workers should also be adequately trained in GAP to ensure that all cultivation stages are properly managed. Implementing these risk mitigations can increase the sustainable supply of red chili, thereby enhancing resilience. The efforts were supported by Andayani et al. (2020) where priority mitigation strategies could be developed through training and the implementation of standard operational procedures. Corozo-Quiñónez et al. (2024) advocated for biological control as a sustainable method to eradicate diseases and pests. Sudarsono et al. (2023) and Islam et al. (2020) showed that every control action within the framework of integrated pest management must be carried out to suppress vector populations in the field. (Islam et al., 2020) emphasized the necessity of comprehensive pest management practices. Additionally, Krasachat and Yaisawarng (2021) and Krasachat (2023) mentioned that GAP positively affected the technical efficiency of chili farming. (Krasachat, 2023) reported the positive impact of GAP on the technical efficiency of chili farming and the importance of reducing chemical toxicity through proper agricultural practices.

Collectors, wholesalers, retailers, and agroindustry traders could mitigate risk by enhancing communication with all actors. Moreover, effective communication about market trends, consumer preferences, delivery schedules, road conditions, available stock, other logistical issues, and price information could significantly improve operations. Frequent updates on price information were particularly critical, considering the daily fluctuations in chili prices, enabling all actors to respond to supply changes. The strategy stakeholders could implement involves establishing a written partnership agreement to support the fulfillment of sales agreements and financial transactions between wholesalers and intercity traders. This research is supported by Spiker et al. (2023) which stated that supply chain improvements should include structural and communicative enhancements to enhance robust trade networks.

Traders can mitigate risks by collaborating with more reliable farmers and being selective in extending capital loans. Ensuring fair price agreements can stabilize financial transactions and maintain supply chain resilience, as stated by Islam and Nursey-Bray (2017). The results showed that building partnerships with community-based informal institutions could mediate relationships between farmers and other relevant entities, including government organizations, private companies, and NGOs. Adane (2023) and Lowe et al. (2019) also emphasized the importance of policy interventions and global partnerships for sustainable development through multi-stakeholder collaborations.

Wholesalers need to control worker operations in sorting red chilies for out-of-town shipments. Retailers, receiving the last large batches face the highest risk of damage due to long distribution times and must re-sort after arrival. Optimizing the processes was crucial since manual sorting can lead to high costs and low quality, necessitating the adoption of automatic grading systems to minimize losses and maintain stable supply, as stated by Huynh et al. (2021), Salim and Fajar (2024), Zhou et al. (2020). In addition, sorting and grading are crucial for perishable product quality control, ensuring uniformity of appearance attributes for farmers, traders, consumers, and the food industry (Aziz et al., 2021; Mohi-Alden et al., 2023; Sajjan et al., 2023). Zhou et al. (2020) suggested that the recruitment of sorting labor was important to minimize supply losses.

Developing new methods for handling dried red chilies is essential, especially when harvests are abundant. Proper post-harvest handling, such as hygienic drying methods, should be used to ensure the agroindustry has access to quality raw materials. Additionally, drying technologies, such as Pulsed Vacuum Drying (PVD), Infrared Assisted Hot Air-drying (IR-HAD), and Hot Air-drying (HAD), are suggested by Deng et al. (2017) to produce high-quality dried peppers commercially. Drying is a popular method for preserving grains, fruits, and vegetables, reducing yield losses, improving product quality, and facilitating transportation, handling, and storage (Ertekin and Firat, 2015). This diversification enhanced the resilience of the red chili supply chain, and Morea and Balzarini (2018) reported that the commercialization of processed primary products significantly improved the agricultural value chain.

The resilience of the red chili supply chain can be enhanced by implementing the aforementioned risk mitigation strategies. These strategies are aimed at reducing the impact and risks faced by each actor within the supply chain. Meanwhile, supply chain resilience focuses on improving the chain's ability to prepare for, respond to, and recover from risks before, during, and after their occurrence. Therefore, developing a structural resilience model is crucial to identify key elements that should guide strategy development in each phase of resilience.

Based on expert interviews and the results of ISM analysis, **Figure 3** illustrates the structural resilience model of the red chili supply chain. At Level 1, foundational elements such as visibility (monitoring structures, processes, and products from upstream to downstream), risk management culture (cultivating the ability to understand and manage risks), flexibility (responding quickly and effectively to disruptions), redundancy (maintaining reserve resources like safety stocks), collaboration (integrating supply chain networks to manage risks), robustness (withstanding pressure without losing function), agility (adapting swiftly to unexpected changes for faster recovery and improved performance post-disruption), market position (maintaining customer loyalty and securing market share), adaptability (gradually or completely changing in response to emerging disruptions), and risk and income sharing (sharing risks and rewards among supply chain players) drive the elements above. These elements must be prioritized across resilience phases to effectively enhance supply chain resilience in East Java. The synthesis analysis integrated findings from HOR 2 and ISM Analysis, as presented in **Table 6**.

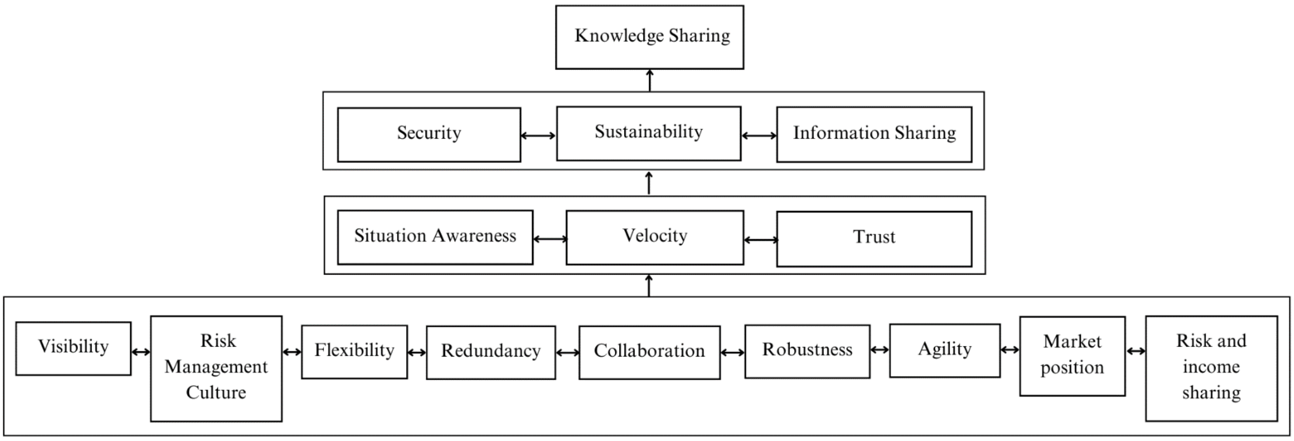


Figure 3. Supply chain resilience structural model in East Java Province.

Table 6. Red chili supply chain resilience strategy through risk mitigation.

SCRES Phase	Strategy	Risk Mitigation	Resilience Element	SCRES Strategies
Pre-disruption	Proactive	● Carry out control and evaluation of farm workers during chili cultivation periodically ● Carry out intensive planting and maintenance of red chili ● Re-sort at the retailer level ● Controlling human resources	● Visibility	● Implemented SCM software that enables real-time tracking of production to distribution ● Weather Change Early Warning System ● Dedicated team that handles risks
			● Risk management culture	● Counseling on risk management
During Disruption	Resistant	● Improve communication with related institutions ● Establish broad partnerships with other farmers	● Flexibility collaboration	● Partnerships with many actors
			● Redundancy	● Chili stock reserves in various places ● Use of storage and drying technology
			● Robustness	● Implementation of GAP to anticipate crop failure ● Post-harvest handling by sorting ● Integrated pest and disease control
			● Risk and income sharing	● Follow agricultural insurance ● Fair Profit Sharing Agreement
Post Disruption	Recover and Growth	Update market price information	● Agility	● Use of Distribution Media ● distribution centers that can be quickly changed and adapted ● Developing locality-specific product variations
			● Market position	● Developing locality-specific product variations
			● Adaptability	● Market Monitoring

Table 6 outlines strategies to enhance the resilience of the red chili supply chain derived from synthesis methods. The resilience of this supply chain in East Java Province is segmented into three phases: before disruption (Phase 1), during disruption (Phase 2), and after disruption (Phase 3). In Phase 1, actors in the supply chain must anticipate potential risks. A proactive strategy is recommended, focusing on improving visibility and fostering a robust risk management culture. This involves implementing SCM software for real-time tracking and establishing an early warning system to alert stakeholders about potential risks. Additionally, forming dedicated risk management teams and providing regular counseling sessions are crucial.

During Phase 2 (disruption phase), a defensive strategy is essential to mitigate severe risks. Collaborative partnerships among stakeholders through mutually beneficial agreements are recommended. Enhancing supply chain flexibility entails collaborating with various suppliers to ensure a consistent chili supply, especially during unpredictable weather. Redundancy can be bolstered by maintaining chili reserves in multiple locations and employing storage technologies to prolong shelf life. Modern drying technologies will facilitate timely access to raw materials for agro-industries, thus enhancing redundancy. Implementing Good Agricultural Practices (GAP) to reduce crop failures and ensuring post-harvest sorting by farmers are vital for maintaining chili quality and market standards. Introducing agricultural insurance and profit-sharing agreements between farmers and traders can further strengthen risk and income sharing.

Phase 3 (Post-Disruption) calls for recovery and growth strategies. Agility can be enhanced by diversifying distribution channels, including traditional markets, modern retail, and e-commerce. Establishing adaptable distribution centers capable of swift adjustments to meet market demands is essential. Developing local-specific products to enhance market position and ensuring customer loyalty through superior service are crucial steps. Monitoring market trends, regulations, and consumer preferences will enhance adaptability.

The study has bridged the gap between agricultural commodity supply chain resilience and supply chain risk management. Previous research has focused more on risk mitigation without fully exploring supply chain resilience to disruptions and failures. The findings of this study, including risk identification, risk mitigation, and strategies to increase the resilience of the red chili supply chain, will greatly help all supply chain actors in maintaining and developing their businesses. Despite the uncertainty inherent in the red chili business, these actors will continue to thrive because they can face various risks. Implementing strategies across all phases can enhance operational expansion for supply chain players. This demonstrates the practical contributions of this research.

The theoretical contribution of this study is to establish a relationship between risk management and the resilience of agricultural commodity supply chains. Not all elements mentioned in previous theories are suitable to be used as elements of supply chain resilience, especially for agricultural products. This is because agricultural products have seasonal characteristics and are easily damaged, unlike the products of the manufacturing industry. However, the limitation is that large agroindustries face more complex risks that have not yet been studied. Future research should encompass these entities and formal financial institutions to broaden risk insights and enhance outcomes. Additionally, predictive models leveraging data mining, machine learning, and IoT technologies could proactively identify and mitigate risks in the red chili supply chain, improving efficiency and resilience.

6. Conclusion

In conclusion, this research was conducted to investigate the risk agents and mitigation strategies for each actor in the red chili supply chain in East Java Province, Indonesia. Immediate priority risk agents for farmers, which included pest and disease attacks, weather uncertainty, and high capital requirements were identified. Meanwhile, traders faced priority risks such as unfulfilled informal contract agreements, perishability of red chili, oversupply during harvest seasons, seasonal instability, and weather uncertainty. For the chili processing agroindustry, the priority risk agents were weather uncertainty and shortages of raw materials. Mitigation actions included adopting Good Agricultural Practices (GAP), establishing selective farmer-trader partnerships, implementing harvest sorting, controlling labor, ensuring effective communication, and using proper drying methods. Appropriate mitigation measures could address risk agents undermining the resilience of the red chili supply chain. In addition, a single mitigation action addressed multiple risk agents.

Risk mitigation efforts aim to enhance supply chain resilience through ten key elements: visibility, risk management culture, flexibility, redundancy, collaboration, robustness, agility, market position, and risk and revenue sharing. These elements underpin three strategies: proactive, resistant, and recovery and growth. Proactive strategies include implementing real-time SCM tracking, a Weather Early Warning System, a dedicated risk management team, and training. Resistant strategies involve partnerships, chili stock reserves, storage and drying technology, GAP implementation, post-harvest management, agricultural insurance, and Fair Profit Sharing Agreements. Recovery and growth strategies focus on flexible distribution channels and adaptable distribution centers. This research provided practical contributions for all actors by identifying the right risk agents, risk mitigation measures, and resilience strategies. Theoretically, the theoretical contribution of this study is to establish a relationship between risk management and the resilience of agricultural commodity supply chains.

Author contributions: Conceptualization, AK and JMMA; methodology, ESH; software, ESH; validation, KH, AK and ESH; formal analysis, JMMA; investigation, AK; resources, AK; data curation, AK; writing—original draft preparation, AK; writing—review and editing, JMMA; visualization, KH; supervision, ESH; project administration, KH; funding acquisition, JMMA. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors are grateful to Jember University’s Institute for Research and Community Service for their tremendous support and financial contribution to the scientific research.

Conflict of interest: The authors declare no conflict of interest.

References

Abrudan, D. B., Daianu, D. C., Maticiuc, M. D., et al. (2022). Strategic leadership, environmental uncertainty, and supply chain risk: An empirical investigation of the agribusiness industry. Agricultural Economics (Zemědělská Ekonomika), 68(5), 171–179. https://doi.org/10.17221/55/2022-agricecon

Adane, A. (2023). Analysis of stakeholders’ roles and interactions in quality coffee production: implications for sustainable land management in Yirgacheffe, Southern Ethiopia. Environment, Development and Sustainability, 26(4), 10163–10182. https://doi.org/10.1007/s10668-023-03140-0

Agyekumhene, C., de Vries, J. R., van Paassen, A., et al. (2018). Digital platforms for smallholder credit access: The mediation of trust for cooperation in maize value chain financing. NJAS: Wageningen Journal of Life Sciences, 86–87(1), 77–88. https://doi.org/10.1016/j.njas.2018.06.001

Ahmad Loti, N. N., Mohd Noor, M. R., & Chang, S. (2020). Integrated analysis of machine learning and deep learning in chili pest and disease identification. Journal of the Science of Food and Agriculture, 101(9), 3582–3594. https://doi.org/10.1002/jsfa.10987

Al Zarliani, W. O., Muzuna, M., & Sugianto, S. (2022). Behavior and Marketing Analysis of Pepper (Piper nigrum L.): A Comparative Study of Farmers, Trading Districts and Retailers in Southeast Sulawesi, Indonesia. Caraka Tani: Journal of Sustainable Agriculture, 38(1), 14. https://doi.org/10.20961/carakatani.v38i1.59193

Ali, A., Mahfouz, A., & Arisha, A. (2017). Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review. Supply Chain Management: An International Journal, 22(1), 16–39. https://doi.org/10.1108/scm-06-2016-0197

Andayani, S. A., Silvianita, S., & Somantri, K. (2020). Risk Detection of Curly Red Chili (Capsicum annum L) Production with

House of Risk. Journal of Agricultural Sciences—Sri Lanka, 15(2), 273–279. https://doi.org/10.4038/jas.v15i2.8811

Asrol, M., Marimin, M., Machfud, M., et al. (2021). Risk Management for Improving Supply Chain Performance of Sugarcane Agroindustry. Industrial Engineering & Management Systems, 20(1), 9–26. https://doi.org/10.7232/iems.2021.20.1.9

Aziz, M. A., Arif Mohamad Nazir, W. M., Ali, A. M., et al. (2021). Chili Ripeness Grading Simulation Using Machine Learning Approach. In: Proceedings of the 2021 IEEE International Conference on Computing (ICOCO). https://doi.org/10.1109/icoco53166.2021.9673572

Behzadi, G., O'Sullivan, M. J., Olsen, T. L., et al. (2017). Robust and resilient strategies for managing supply disruptions in an agribusiness supply chain. International Journal of Production Economics, 191, 207–220. https://doi.org/10.1016/j.ijpe.2017.06.018

Béné, C. (2020). Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. Food Security, 12(4), 805–822. https://doi.org/10.1007/s12571-020-01076-1

Bhutia L, K., VK, K., Meetei NG, T., et al. (2018). Effects of Climate Change on Growth and Development of Chilli. Agrotechnology, 07(02). https://doi.org/10.4172/2168-9881.1000180

Blessley, M., & Mudambi, S. M. (2022). A trade war and a pandemic: Disruption and resilience in the food bank supply chain. Industrial Marketing Management, 102, 58–73. https://doi.org/10.1016/j.indmarman.2022.01.002

Brusset, X., & Teller, C. (2017). Supply chain capabilities, risks, and resilience. International Journal of Production Economics, 184, 59–68. https://doi.org/10.1016/j.ijpe.2016.09.008

Central Bureau of Statistics Indonesia. (2022). Statistics Indonesia. Badan Pusat Statistik.

Chenarides, L., Manfredo, M., & Richards, T. J. (2020). COVID-19 and Food Supply Chains. Applied Economic Perspectives and Policy, 43(1), 270–279. https://doi.org/10.1002/aepp.13085

Chitra, R., Balasudarsun, N. L., Sathish, M., et al. (2023). Supply chain modelling in organic farming for sustainable profitability. Agricultural Economics (Zemědělská Ekonomika), 69(6), 255–266. https://doi.org/10.17221/44/2023-agricecon

Choudhary, N. A., Singh, S., Schoenherr, T., et al. (2022). Risk assessment in supply chains: a state-of-the-art review of methodologies and their applications. Annals of Operations Research, 322(2), 565–607. https://doi.org/10.1007/s10479-022-04700-9

Coopmans, I., Bijttebier, J., Marchand, F., et al. (2021). COVID-19 impacts on Flemish food supply chains and lessons for agri-food system resilience. Agricultural Systems, 190, 103136. https://doi.org/10.1016/j.agsy.2021.103136

Corozo-Quiñónez, L., Chirinos, D. T., Saltos-Rezabala, L., et al. (2024). Can Capsicum spp. genotypes resist simultaneous damage by both Phytophthora capsici and Bemisia tabaci? Can natural enemies of Bemisia complement plant resistance? Frontiers in Ecology and Evolution, 11. https://doi.org/10.3389/fevo.2023.1275953

Dai, M., & Liu, L. (2020). Risk assessment of agricultural supermarket supply chain in big data environment. Sustainable Computing: Informatics and Systems, 28, 100420. https://doi.org/10.1016/j.suscom.2020.100420

De, I., & Pohit, S. (2021). Garnering the fiscal stimulus: A bargaining game. Economic and Political Weekly, 56(3), 16-19.

Deng, L. Z., Yang, X. H., Mujumdar, A. S., et al. (2017). Red pepper (Capsicum annuum L.) drying: Effects of different drying methods on drying kinetics, physicochemical properties, antioxidant capacity, and microstructure. Drying Technology, 36(8), 893–907. https://doi.org/10.1080/07373937.2017.1361439

Dewi, R. K., & Dewi, N. P. (2017). Risk Mitigation of Red Chili Production in the Village Besakih, Bali Province. Journal of Economics and Sustainable Development, 8(4), 197-201.

Dewi, R. K., Parining, N., & Harsojuwono, B. A. (2023). Mitigation of red chilli supply chain risks in Bali, Indonesia. International Journal of Agriculture and Food Science, 5(2), 103–112. https://doi.org/10.33545/2664844x.2023.v5.i2b.152

Djomo, C. R. F., Ukpe, H. U., Ngo, N. V., et al. (2020). Perceived effects of climate change on profit efficiency among small scale chili pepper marketers in Benue State, Nigeria. GeoJournal, 86(4), 1849–1862. https://doi.org/10.1007/s10708-020-10163-x

Ebert, A. W. (2017). Vegetable Production, Diseases, and Climate Change. World Agricultural Resources and Food Security, 103–124. https://doi.org/10.1108/s1574-871520170000017008

Ertekin, C., & Firat, M. Z. (2015). A comprehensive review of thin-layer drying models used in agricultural products. Critical Reviews in Food Science and Nutrition, 57(4), 701–717. https://doi.org/10.1080/10408398.2014.910493

Esteso, A., Alemany, M. M. E., Ortiz, A., et al. (2021). Optimization model to support sustainable crop planning for reducing unfairness among farmers. Central European Journal of Operations Research, 30(3), 1101–1127. https://doi.org/10.1007/s10100-021-00751-8

Fauzan, M., & Fanestia, I. M. C. (2022). Supply Chain Resources of Red Chili Based on Food Supply Chain Network in Kulonprogo Indonesia. In: Proceedings of the 6th International Conference of Food, Agriculture, and Natural Resource (IC-FANRES 2021). pp. 174–183. https://doi.org/10.2991/absr.k.220101.023

Fernández-González, R., Puíme-Guillén, F., & Panait, M. (2022). A case study of agri-food systems in rural Spain: Impacts, responses and institutional lessons. Agricultural Economics (Zemědělská Ekonomika), 68(5), 159–170. https://doi.org/10.17221/65/2022-agricecon

Fudholi, A., Othman, M. Y., Ruslan, M. H., et al. (2013). Drying of MalaysianCapsicum annuumL. (Red Chili) Dried by Open and Solar Drying. International Journal of Photoenergy, 2013, 1–9. https://doi.org/10.1155/2013/167895

Gu, H., & Wang, C. (2020). Impacts of the COVID-19 pandemic on vegetable production and countermeasures from an agricultural insurance perspective. Journal of Integrative Agriculture, 19(12), 2866-2876. https://doi.org/10.1016/S2095-3119(20)63429-3

Guhathakurta, R. (2022). SCOR Model: Key Processes, Advantages and Disadvantages. IndraStra Global, 7(12).

Han, Y., Chong, W. K., & Li, D. (2020). A systematic literature review of the capabilities and performance metrics of supply chain resilience. International Journal of Production Research, 58(15), 4541–4566. https://doi.org/10.1080/00207543.2020.1785034

Harniati, H., Widodo, T., & Tasrif, A. (2022). Disruption to Supply Chain of Red Chili. International Symposium Southeast Asia Vegetable 2021 (SEAVEG 2021), 238–246. https://doi.org/10.2991/978-94-6463-028-2_26

Hendry, L. C., Stevenson, M., MacBryde, J., et al. (2019). Local food supply chain resilience to constitutional change: the Brexit effect. International Journal of Operations & Production Management, 39(3), 429–453. https://doi.org/10.1108/ijopm-03-2018-0184

Hernández-Pérez, T., Gómez-García, M. del R., Valverde, M. E., et al. (2020). Capsicum annuum (hot pepper): An ancient Latin-American crop with outstanding bioactive compounds and nutraceutical potential. A review. Comprehensive Reviews in Food Science and Food Safety, 19(6), 2972–2993. https://doi.org/10.1111/1541-4337.12634

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: a literature review. International Journal of Production Research, 53(16), 5031–5069.

Hohenstein, N. O., Feisel, E., Hartmann, E., et al. (2015). Research on the phenomenon of supply chain resilience. International Journal of Physical Distribution & Logistics Management, 45(1/2), 90–117. https://doi.org/10.1108/ijpdlm-05-2013-0128

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. Transportation Research Part E: Logistics and Transportation Review, 125, 285–307. https://doi.org/10.1016/j.tre.2019.03.001

Hung, P. Q., & Khai, H. V. (2020). Transaction cost, price risk perspective and marketing channel decision of small-scale chili farmers in Tra Vinh Province, Vietnam. Asian Journal of Agriculture and Rural Development, 10(1), 68–80. https://doi.org/10.18488/journal.1005/2020.10.1/1005.1.68.80

Huynh, Q. K., Nguyen, C. N., Vo-Nguyen, H. P., et al. (2021). Crack Identification on the Fresh Chilli (Capsicum) Fruit Destemmed System. Journal of Sensors, 2021, 1–10. https://doi.org/10.1155/2021/8838247

Ibikoule, G. E., Lee, J., & Godonou, L. A. (2024). Smallholders' vulnerability in the maize market: An analysis of marketing channels to improve the role of cooperatives in Benin. Heliyon, 10(6), e27746. https://doi.org/10.1016/j.heliyon.2024.e27746

Islam, A. H. M. S., Schreinemachers, P., & Kumar, S. (2020). Farmers' knowledge, perceptions and management of chili pepper anthracnose disease in Bangladesh. Crop Protection, 133, 105139. https://doi.org/10.1016/j.cropro.2020.105139

Islam, M. T., & Nursey-Bray, M. (2017). Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. Journal of Environmental Management, 200, 347–358. https://doi.org/10.1016/j.jenvman.2017.05.092

Keswani, H., & Vlachos, I. (2022). Achieving Supply chain Resilience through risk management and mitigation discipline. In: Proceedings of the International Conference on Industrial Engineering and Operations Management; Istanbul, Turkey.

Krasachat, W. (2023). The Effect of Good Agricultural Practices on the Technical Efficiency of Chili Production in Thailand. Sustainability, 15(1), 866. https://doi.org/10.3390/su15010866

Krasachat, W., & Yaisawarng, S. (2021). Directional Distance Function Technical Efficiency of Chili Production in Thailand. Sustainability, 13(2), 741. https://doi.org/10.3390/su13020741

Krishna, A. V., Mounika, T., Geetha, G. S., et al. (2024). An Efficient Approach for Smart Cold Storage Management System Using IoT. In: Proceedings of the International Conference on Communications and Cyber Physical Engineering 2018. https://doi.org/10.1007/978-981-99-7137-4_23

Kuizinaitė, J., Morkūnas, M., & Volkov, A. (2023). Assessment of the Most Appropriate Measures for Mitigation of Risks in the

Agri-Food Supply Chain. Sustainability, 15(12), 9378. https://doi.org/10.3390/su15129378

Kumar, J. (2024). Supply Chain Resilience and Risk Management: Strategies for Mitigating Global Supply Chain Disruptions. Educational Administration: Theory and Practice, 2169–2175. https://doi.org/10.53555/kuey.v30i6.5680

Kumar, P., & Kumar Singh, R. (2021). Strategic framework for developing resilience in Agri-Food Supply Chains during COVID 19 pandemic. International Journal of Logistics Research and Applications, 25(11), 1401–1424. https://doi.org/10.1080/13675567.2021.1908524

Liu, Y., Eckert, C. M., & Earl, C. (2020). A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Systems with Applications, 161, 113738. https://doi.org/10.1016/j.eswa.2020.113738

Lowe, P., Phillipson, J., Proctor, A., et al. (2019). Expertise in rural development: A conceptual and empirical analysis. World Development, 116, 28–37. https://doi.org/10.1016/j.worlddev.2018.12.005

Lu, Q., Liao, C., Chen, M., et al. (2024). Platform financing or bank financing in agricultural supply chains: The impact of platform digital empowerment. European Journal of Operational Research, 315(3), 952–964. https://doi.org/10.1016/j.ejor.2023.12.024

Lu, Z., Li, H., & Wu, J. (2024). Exploring the impact of financial literacy on predicting credit default among farmers: An analysis using a hybrid machine learning model. Borsa Istanbul Review, 24(2), 352–362. https://doi.org/10.1016/j.bir.2024.01.006

Luo, Y., Huang, D., Han, Y., et al. (2022). Storage losses, market development and household maize-selling decisions in China. China Agricultural Economic Review, 15(1), 78–94. https://doi.org/10.1108/caer-10-2021-0201

Mahbubi, A., Ruspendi, I., & Ibrohim, M. S. (2024). Strengthening the Value Chain Resilience of Indonesian Agricultural Fintech in the Aftermath of the Covid-19 Pandemic. International Journal on Food System Dynamics, 15(1), 44–54. https://doi.org/10.18461/IJFSD.V15I1.I4

Mailena, L., Indrawanto, C., & Astuti, E. P. (2021). Risk management of chilli supply chains using weighted failure mode effect analysis. IOP Conference Series: Earth and Environmental Science, 782(2), 022004. https://doi.org/10.1088/1755-1315/782/2/022004

Mohi-Alden, K., Omid, M., Soltani Firouz, M., et al. (2023). A machine vision-intelligent modelling based technique for in-line bell pepper sorting. Information Processing in Agriculture, 10(4), 491–503. https://doi.org/10.1016/j.inpa.2022.05.003

Morea, D., & Balzarini, M. (2018). Financial sustainability of a public-private partnership for an agricultural development project in Sub-Saharan Africa. Agricultural Economics (Zemědělská Ekonomika), 64(9), 389–398. https://doi.org/10.17221/161/2017-agricecon

Muflikh, Y. N., Smith, C., Brown, C., et al. (2021). Analysing price volatility in agricultural value chains using systems thinking: A case study of the Indonesian chilli value chain. Agricultural Systems, 192, 103179. https://doi.org/10.1016/j.agsy.2021.103179

Munarso, S. J., Kailaku, S. I., Arif, A. bin, Budiyanto, A., et al. (2020). Quality Analysis of Chili Treated with Aqueous Ozone Treatment and Improved Transportation and Handling Technology. International Journal of Technology, 11(1), 37. https://doi.org/10.14716/ijtech.v11i1.3213

Nasruddin, A., Agus, N., Saubil, A., et al. (2020). Effects of Mulch Type, Plant Cultivar, and Insecticide Use on Sweet Potato Whitefly Population in Chili Pepper. Scientifica, 2020, 1–7. https://doi.org/10.1155/2020/6428426

Núñez, S. R., Jiménez, D. B., & Re, S. S. (2016). Territorial agro-food chains. Tensions and insights from the dairy sector of the Ecuadorian Amazon. Lecturas de Economía, 84, 179. https://doi.org/10.17533/udea.le.n84a06

Nguyen, X. H., Le, T. A., Nguyen, A. T., et al. (2021). Supply chain risk, integration, risk resilience and firm performance in global supply chain: Evidence from Vietnam pharmaceutical industry. Uncertain Supply Chain Management, 9(4), 779–796. https://doi.org/10.5267/j.uscm.2021.8.010

Nyoman Pujawan, I., & Geraldin, L. H. (2009). House of risk: a model for proactive supply chain risk management. Business Process Management Journal, 15(6), 953–967. https://doi.org/10.1108/14637150911003801

Pettit, T. J., Croxton, K. L., & Fiksel, J. (2019). The Evolution of Resilience in Supply Chain Management: A Retrospective on Ensuring Supply Chain Resilience. Journal of Business Logistics, 40(1), 56–65. https://doi.org/10.1111/jbl.12202

Rahman, M. M., Nguyen, R., & Lu, L. (2022). Multi-level impacts of climate change and supply disruption events on a potato supply chain: An agent-based modeling approach. Agricultural Systems, 201, 103469. https://doi.org/10.1016/j.agsy.2022.103469

Ríos, S., Benítez, D., & Soria, S. (2016). Territorial agrifood chains. Tensions and lessons learned from the dairy sector of the Ecuadorian Amazon (Spanish). Lecturas de Economía, 84. https://doi.org/10.17533/udea.le.n84a06

Saitone, T. L., Sexton, R. J., & Malan, B. (2018). Price premiums, payment delays, and default risk: understanding developing country farmers' decisions to market through a cooperative or a private trader. Agricultural Economics, 49(3), 363–380. https://doi.org/10.1111/agec.12422

Sajjan, M., Kulkarni, L., S. Anami, B., et al. (2023). Chilli Dryness and Ripening Stages Assessment Using Machine Vision. International Journal of Image, Graphics and Signal Processing, 15(6), 67–80. https://doi.org/10.5815/ijigsp.2023.06.06

Salim, R., & Fajar, A. N. (2024). Object Detection of Chili Using Convolutional Neural Network YOLOV7. Journal of Theoretical and Applied Information Technology, 102(6), 2419-2427.

Savitha, B., & Kumar K., N. (2016). Non-performance of financial contracts in agricultural lending. Agricultural Finance Review, 76(3), 362–377. https://doi.org/10.1108/afr-01-2016-0001

Simbizi, D., Benabbou, L., & Urli, B. (2021). Systematic Literature Reviews in Supply chain resilience: A Systematic Literature Review. In: Proceedings of the International Conference on Industrial Engineering and Operations Management. https://doi.org/10.46254/an11.20210056

Singh, C. S., Soni, G., & Badhotiya, G. K. (2019). Performance indicators for supply chain resilience: review and conceptual framework. Journal of Industrial Engineering International, 15(S1), 105–117. https://doi.org/10.1007/s40092-019-00322-2

Smith, V. H. (2016). Producer Insurance and Risk Management Options for Smallholder Farmers: Table 1. The World Bank Research Observer, 31(2), 271–289. https://doi.org/10.1093/wbro/lkw002

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. Computers & Industrial Engineering, 74, 11–25. https://doi.org/10.1016/j.cie.2014.04.019

Spiker, M. L., Welling, J., Hertenstein, D., et al. (2023). When increasing vegetable production may worsen food availability gaps: A simulation model in India. Food Policy, 116, 102416. https://doi.org/10.1016/j.foodpol.2023.102416

Stone, J., & Rahimifard, S. (2018). Resilience in agri-food supply chains: a critical analysis of the literature and synthesis of a novel framework. Supply Chain Management: An International Journal, 23(3), 207–238. https://doi.org/10.1108/scm-06-2017-0201

Sudarsono, S., Melina, M., & Nasruddin, A. (2023). The primary inoculum sources in the epidemiology of pepper yellow leaf curl indonesia virus on chili plants. Pakistan Journal of Phytopathology, 35(1), 93–101. https://doi.org/10.33866/phytopathol.035.01.0853

Suryani, A., Masyhuri, M., Waluyati, L. R., et al. (2023). Risk Analysis on the Cassava Value Chain in Central Lampung Regency. AGRARIS: Journal of Agribusiness and Rural Development Research, 9(2), 150–173. https://doi.org/10.18196/agraris.v9i2.333

Susanawati, Akhmadi, H., Fauzan, M., & Rozaki, Z. (2021). Supply chain efficiency of red chili based on the performance measurement system in Yogyakarta, Indonesia. Open Agriculture, 6(1), 202–211. https://doi.org/10.2991/absr.k.220101.023

Susanawati, & Hida, A. J. W. (2023). Supply chain performance of red chili from coastal land farming in the production center of Bantul Indonesia. E3S Web of Conferences, 467, 06002. https://doi.org/10.1051/e3sconf/202346706002

Susanawati, Fauzan, M., & Fanestia, I. M. C. (2022). Supply Chain Resources of Red Chili Based on Food Supply Chain Network in Kulonprogo Indonesia. In: Proceedings of the 6th International Conference of Food, Agriculture, and Natural Resource (IC-FANRES 2021). https://doi.org/10.2991/absr.k.220101.023

Taiti, C., Costa, C., Migliori, C. A., et al. (2019). Correlation Between Volatile Compounds and Spiciness in Domesticated and Wild Fresh Chili Peppers. Food and Bioprocess Technology, 12(8), 1366–1380. https://doi.org/10.1007/s11947-019-02297-9

Tang, R., Supit, I., Hutjes, R., et al. (2023). Modelling growth of chili pepper (Capsicum annuum L.) with the WOFOST model. Agricultural Systems, 209, 103688. https://doi.org/10.1016/j.agsy.2023.103688

Teniwut, W. A., Hamid, S. K., & Makailipessy, M. M. (2020). Mitigation strategy on the uncertainty supply chain of the fisheries sector in small islands, Indonesia. Uncertain Supply Chain Management, 705–712. https://doi.org/10.5267/j.uscm.2020.8.002

Ul Hasan, M., Ullah Malik, A., Anwar, R., et al. (2021). Postharvest Aloe vera gel coating application maintains the quality of harvested green chilies during cold storage. Journal of Food Biochemistry, 45(4). https://doi.org/10.1111/jfbc.13682

Um, J., & Han, N. (2020). Understanding the relationships between global supply chain risk and supply chain resilience: the role of mitigating strategies. Supply Chain Management: An International Journal, 26(2), 240–255. https://doi.org/10.1108/scm-06-2020-0248

Wahyuningtyas, A. S. H., Haryati, N., Pratiwi, D. E., et al. (2021). Risk Mitigation Strategies in Semi-Organic Rice Supply Chains: Lesson Learned from the Involved Actors. AGRARIS: Journal of Agribusiness and Rural Development Research, 7(2), 241–255. https://doi.org/10.18196/agraris.v7i2.10126

Wang, Z., Gao, J. M., Wang, R. X., et al. (2018). Failure Mode and Effects Analysis by Using the House of Reliability-Based Rough VIKOR Approach. IEEE Transactions on Reliability, 67(1), 230–248. https://doi.org/10.1109/tr.2017.2778316

Wegren, S. K. (2018). Russian grain production: too much of a good thing? Post-Communist Economies, 1–12. https://doi.org/10.1080/14631377.2018.1470856

Zhang, Y., & Cheng, H. (2023). Novel Double Auction Mechanisms for Agricultural Supply Chain Trading. IEEE Access, 11, 50382–50397. https://doi.org/10.1109/access.2023.3272118

Zhao, G., Liu, S., & Lopez, C. (2017). A literature review on risk sources and resilience factors in agri-food supply chains. In: Proceedings of the Collaboration in a Data-Rich World: 18th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2017; 18–20 September 2017; Vicenza, Italy. pp. 739–752.

Zhou, J., Han, F., Li, K., & Wang, Y. (2020). Vegetable production under COVID-19 pandemic in China: An analysis based on the data of 526 households. Journal of Integrative Agriculture, 19(12), 2854-2865. https://doi.org/10.1016/S2095-3119(20)63366-4