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# Mapping production risk in clove (*Syzygium aromaticum* L.) plantations using a fishbone diagram

# Pemetaan risiko produksi pada perkebunan cengkeh (*Syzygium aromaticum* L.) menggunakan diagram *fishbone*

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**ABSTRACT**
Clove (*Syzygium aromaticum* L.) is a strategic spice commodity that plays an important role in both domestic consumption and export markets in Indonesia. Despite its high economic value, clove production in Solok Regency has experienced considerable fluctuations in recent years, indicating the presence of production risks that have not been comprehensively identified. This study aims to identify the root causes of production risk in clove farming using a qualitative exploratory approach based on fishbone diagram analysis. The study was conducted in Gunung Talang District, a major clove-producing area in Solok Regency. Primary data were collected through structured surveys and field observations involving 30 purposively selected clove farmers. The results indicate that clove farming serves as a primary livelihood activity and is exposed to multiple interconnected risk factors. A total of 14 sources of production risk were identified and classified into four main categories: natural disasters, human resources, pest and disease attacks, and production facilities and infrastructure. These findings demonstrate that production risks in clove farming are multidimensional and interrelated rather than driven by single factors. This study provides empirical and conceptual insights by developing a root cause–based production risk analysis framework that can support more targeted, contextual, and sustainable risk management strategies for clove farming.

**ABSTRAK**
Cengkeh (*Syzygium aromaticum* L.) merupakan komoditas rempah strategis yang berperan penting dalam konsumsi domestik dan pasar ekspor di Indonesia. Meskipun memiliki nilai ekonomi yang tinggi, produksi cengkeh di Kabupaten Solok mengalami fluktuasi yang cukup signifikan dalam beberapa tahun terakhir, yang mengindikasikan adanya risiko produksi yang belum teridentifikasi secara komprehensif. Penelitian ini bertujuan untuk mengidentifikasi akar penyebab risiko produksi pada usahatani cengkeh dengan menggunakan pendekatan eksploratif kualitatif berbasis analisis diagram fishbone. Penelitian dilaksanakan di Kecamatan Gunung Talang sebagai salah satu sentra produksi cengkeh di Kabupaten Solok. Data primer dikumpulkan melalui survei terstruktur dan observasi lapangan terhadap 30 petani cengkeh yang dipilih secara purposif. Hasil penelitian menunjukkan bahwa usahatani cengkeh merupakan sumber mata pencaharian utama petani dan menghadapi berbagai faktor risiko yang saling terkait. Sebanyak 14 sumber risiko produksi berhasil diidentifikasi dan dikelompokkan ke dalam empat kategori utama, yaitu bencana alam, sumber daya manusia, serangan hama dan penyakit, serta sarana dan prasarana produksi. Temuan ini menunjukkan bahwa risiko produksi pada usahatani cengkeh bersifat multidimensional dan saling berinteraksi, bukan disebabkan oleh satu faktor tunggal. Penelitian ini memberikan kontribusi empiris dan konseptual melalui pengembangan kerangka analisis risiko produksi berbasis identifikasi akar masalah, yang dapat menjadi dasar dalam perumusan strategi pengelolaan risiko usahatani cengkeh yang lebih tepat sasaran, kontekstual, dan berkelanjutan.

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## INTRODUCTION

Plantation crops are strategic commodities that contribute significantly to Indonesia's economic development. These commodities generate foreign exchange earnings and support rural livelihoods. Given their significance, the plantation sector receives priority in national development agendas. This priority is formally established in Article 1(1) of Law Number 18 of 2024 concerning Plantations, which mandates sustainability guarantees and functional enhancement of plantations to achieve public welfare and prosperity (Samiun et al., 2024).

Indonesia's primary plantation commodities include palm oil, rubber, cocoa, pepper, cloves, tobacco, nutmeg, and vanilla. Cloves (*Syzygium aromaticum L.*) stand as a particularly valuable spice commodity with substantial economic importance for both local Indonesian communities and global markets. As native Indonesian spices, cloves have emerged as one of the nation's leading export commodities. These plants find extensive applications across diverse industries, including food processing, pharmaceuticals, and cosmetics. Indonesia, as the world's largest clove producer, holds a dominant position in the global clove market.

According to FAO (2022), Indonesia exported an average of 130,000 tons of cloves annually during 2016-2020, accounting for 72.6% of global clove exports. Indonesian cloves are widely demanded in Asian, European, and American markets due to their distinctive quality characteristics. With growing global demand, maintaining production stability and quality standards becomes crucial for Indonesia to preserve its competitive edge in export markets (Anjani et al., 2024). However, increasing market demand also intensifies pressure on production systems, making clove farming more vulnerable to production risks and supply instability.

West Sumatra Province is one of Indonesia's clove-producing regions, with plantation areas reaching 9,948.05 hectares in 2023 of the total area of 575,218 ha of clove plantations in Indonesia (Ministry of Agriculture, 2023). However, the province has experienced a marked decline in production over the past eight years, with output plummeting from 5,313.18 tons in 2017 to merely 2,240.37 tons in 2022 (Figure 1).

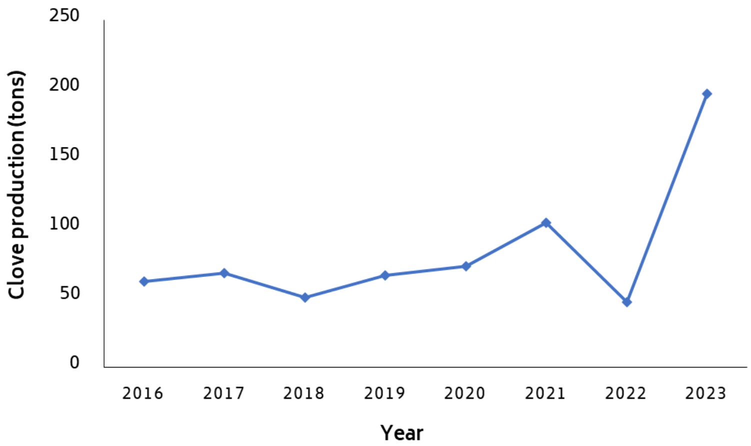


**Figure 1.** Clove production of Gunung Talang District in the last 8 years (tons) (BPS,2023)

Solok Regency is a major contributor to clove production in West Sumatra, accounting for a substantial share of the province's total output (BPS, 2023). Within this regency, Gunung Talang District serves as an important clove production center but exhibits pronounced year-to-year production fluctuations. A sharp decline was observed in 2022, followed by a partial recovery in the subsequent year; however, production levels remain well below the district's estimated production potential relative to its plantation area. These persistent fluctuations and the gap between actual and potential output suggest the presence of significant production risks in clove farming in Gunung Talang District (Paloma et al., 2019).

Farmers generally face three main types of risk—production risk, price risk, and income risk—with production risk posing the greatest challenge because it directly affects yield quantity and quality. Given the nature-dependent character of agriculture, farming systems are inherently vulnerable to environmental and management-related disturbances. Key sources of production risk include pest and disease outbreaks, weather variability, water availability, and input-related constraints (Kaleka et al., 2020). In Gunung Talang District, fluctuations in clove production reflect the combined influence of internal and external risk factors, particularly climatic conditions characterized by persistently high rainfall. Internal production constraints include suboptimal seed quality and cultivation practices, with many farmers relying on poor-quality planting materials that are more vulnerable to pests, combined with limited technical knowledge that further reduces productivity (Ware et al, 2025).

This research adopts a structured approach to production risk identification by comprehensively categorizing risk sources into four main groups: natural disasters, human resources, pest and disease attacks, and production facilities and infrastructure. These categories are derived from key factors influencing crop production, as reported by Binambuni et al. (2025). The study applies fishbone diagram analysis as a systematic tool to identify and organize the root causes of production risk in clove farming. Furthermore, while previous studies have mainly proposed general adaptation strategies, this research emphasizes integrated risk identification as a foundation for developing preventive risk management measures.

Research that specifically and comprehensively examines production risk in clove farming remains limited and has not been widely addressed using a systematic and integrated approach. Most existing studies have focused on production risks in other agricultural commodities, such as rice, coffee, shallot, coconut, and citrus, particularly in relation to climate variability, pest and disease pressures, and farmers' income (Paloma et al., 2019; Baroroh et al., 2021; Minarsih et al., 2019; Nurliana et al., 2024). Studies on clove farming have primarily emphasized cultivation practices, productivity, or specific pest issues, without providing a comprehensive, causal-based mapping of production risks.

This study addresses the identified research gap by developing an integrated framework for clove production risk analysis based on root cause identification. By identifying 14 sources of production risk classified into four major categories—natural disasters, human resources, pest and disease, and production facilities and infrastructure—this research provides a structured risk map of clove farming in Gunung Talang District. The findings contribute empirical insights that can support more precise and sustainable risk management strategies in clove production systems.

## RESEARCH METHODS

The study was conducted in Gunung Talang District, Solok Regency, which was purposively selected because this area represents one of the largest clove plantation zones in Solok Regency and exhibits fluctuating production levels compared to other districts. This distinctive production variability made Gunung Talang District an ideal location to analyze clove production risks. For sampling, the study employed a non-probability purposive sampling technique, which is a sampling method based on specific criteria (Sugiyono, 2018). The sample selection criteria targeted clove farmers with at least three years of continuous clove production experience. Based on these criteria, the study involved 30 farmer respondents. This sample size was considered adequate given the selective nature of the sampling approach and the focused scope of the study. Additionally, referring to Roscoe's rule of thumb in social science research, a minimum of 30 respondents is generally considered acceptable to represent a population and is suitable for basic quantitative analysis, including validity and reliability testing (Sugiyono, 2020).

The primary analytical tool used to identify risk sources in clove plantations was the fishbone diagram (also known as the Ishikawa Diagram or Cause-and-Effect Diagram). The fishbone diagram was developed by Dr. Kaoru Ishikawa in 1943 (Sadipun, 2023) and serves as a graphical technique to systematically sort and connect various factors influencing a production process. As Hariance et al. (2023) explain, the fishbone diagram is particularly useful for identifying problems stemming from multiple sources and causes that contribute to an overall issue. In this study, we specifically constructed a fishbone diagram to comprehensively identify and visualize the diverse causes and sources of production risk affecting clove plantations in Gunung Talang District. The interview results were tabulated and triangulated to obtain production risk sources. The diagram helped map out the complex interrelationships between different risk factors and their potential impacts on clove production outcomes.

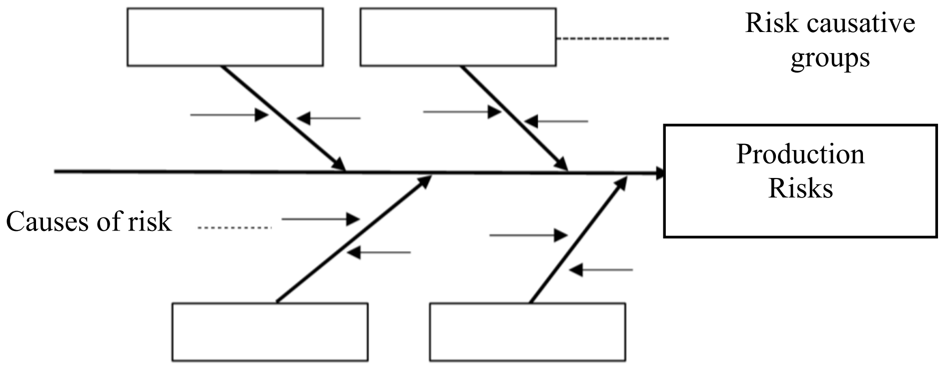


**Figure 2.** Fishbone Diagram

The construction of the fishbone diagram followed the systematic approach outlined by Gaspersz (1997), comprising five key steps (Figure 2). First, the basic diagram structure was established by collectively defining the primary risk factors, which are represented as the "effect" and visually depicted as the "fish head" in the diagram. From this central element, the main "spine" is drawn to organize all contributing causes. Second, in-depth interviews were conducted with selected respondents to identify and document the main problems affecting clove production, with particular attention to discrepancies between current operational and ideal production conditions. This stage involves comprehensive data collection from farmers and stakeholders to ensure all critical issues are well-captured. Third, detailed field observations and structured interviews were conducted with clove farmers in Gunung Talang District to identify and verify all factors influencing or directly causing production problems. This empirical approach helped ground the analysis in actual field conditions and farmer experiences. Fourth, causal factors were systematically categorized into logical groups based on established categories of causes.

This step enables much clearer analysis of relationships between different types of production constraints. Finally, the visual construction of the fishbone diagram from problem analysis and cause identification. The diagram clearly illustrates the interconnections among various production risks.

## RESULTS & DISCUSSIONS

*Characteristics of clove farmers in Gunung Talang District*

The survey results reveal significant gender disparities among clove farmers in the study area, with male farmers dominating the sector at 93.3% (n=28) compared to just 6.7% female participation (n=2). This pronounced gender imbalance reflects the physically demanding nature of clove cultivation, particularly in maintenance and harvesting operations that require substantial strength and tree-climbing abilities. As shown in Table 1, these findings align with the research by Trisnawati et al (2018) on agricultural labor productivity, which identifies gender as a key indicator of work capacity. Their study demonstrates that male farmers typically possess greater physical strength and can dedicate more time to agricultural activities compared to their female counterparts. The male dominance in Gunung Talang's clove farming sector is further reinforced by the challenging terrain of production areas, as most plantations are located on steep hillsides that demand exceptional physical endurance from workers.

**Table 1.** Characteristics of clove farmers

| No | Characteristics | | | Amount (People) | Percentage |
|---|---|---|---|---|---|
| 1. | Gender | | | | |
| | | a. | Male | 28 | 93.33% |
| | | b. | Female | 2 | 6.67% |
| | **Total** | | | **30** | **100%** |
| 2. | Ages | | | | |
| | | a. | 26-49 | 10 | 33.33% |
| | | b. | 50-64 | 10 | 33.33% |
| | | c. | >64 | 10 | 33.33% |
| | **Total** | | | **30** | **100%** |
| 3. | Education | | | | |
| | | a. | Elementary | 10 | 33.33% |
| | | b. | Junior high school | 5 | 16.67% |
| | | c. | Senior high school | 10 | 33.33% |
| | | d. | Diploma | 1 | 3.33% |
| | | e. | Bachelor degree | 4 | 13.33% |
| | **Total** | | | **30** | **100%** |
| 4. | Main job | | | | |
| | | a. | Farmer | 21 | 70% |
| | | b. | Traders | 5 | 16.67% |
| | | c. | Employee | 4 | 13.33% |
| | **Total** | | | **30** | **100%** |
| 5. | Family member | | | | |
| | | a. | 1-2 | 1 | 3.33% |
| | | b. | 3-4 | 14 | 46.67% |
| | | c. | 5-6 | 12 | 40.00% |
| | | d. | >6 | 3 | 10.00% |
| | **Total** | | | **30** | **100%** |
| 6. | Clove gardening experience | | | | |
| | | a. | 5-25 | 11 | 36.67% |
| | | b. | 25-50 | 19 | 63.33% |
| | **Total** | | | **30** | **100%** |
| 7. | Land own | | | | |
| | | a. | 0.1-0.2 | 5 | 16.67% |
| | | b. | 0.2-0.5 | 18 | 60.00% |
| | | c. | 0.5-1 | 3 | 10.00% |
| | | d. | >1 | 4 | 13.33% |
| | **Total** | | | **30** | **100%** |
| 8. | Land ownership status | | | | |
| | Owner | | | 30 | 100% |
| | **Total** | | | **30** | **100%** |

According to the Central Statistics Agency classification, the productive age range spans 15-64 years, with 15-49 years considered very productive and 50-64 years as productive. Age significantly impacts workforce productivity, and our study confirms that respondent farmers within productive age ranges demonstrate substantially higher productivity levels compared to non-productive age farmers (Trisnawati et al., 2018). The research reveals that clove farmers in Gunung

Talang District age ranged from 34 to 73 years old. Educational backgrounds vary from elementary to undergraduate level, although most farmers have completed elementary or senior high school, indicating general compliance with Indonesia's 12-year compulsory education policy. This level of education shapes how farmers manage and make decisions in their farming activities.

Farming is the main source of livelihood for the majority of respondents, while the rest supplement their income through trading or formal employment, reflecting the district's fertile land and favorable agroecological conditions. Most households consist of three to four members, a family size that supports farming activities through the availability of family labor and contributes to income generation. In addition, farmers generally possess extensive experience, with many having cultivated cloves for several decades, enabling them to anticipate and address production challenges effectively (Listiana, 2020). Land ownership is another key factor influencing production, as farm size varies considerably but all respondents cultivate their own land. This ownership status provides greater autonomy in farm management and decision-making, which supports the long-term sustainability of clove farming in Gunung Talang District.

*Identifying sources of clove production risk*

The initial stage of risk analysis involves comprehensive risk identification. For this study, we identified risk factors affecting clove production in Gunung Talang District through in-depth interviews and direct field observations of farmers' clove plantations. The collected data was systematically analyzed and visually represented using a fishbone diagram, an effective tool for detailed categorization of various risk factors. In our constructed diagram, the fish head symbolically represents the overarching production risks faced by clove farmers in Gunung Talang District, while the bones (body) of the diagram systematically organize the grouped risk factors influencing clove production.

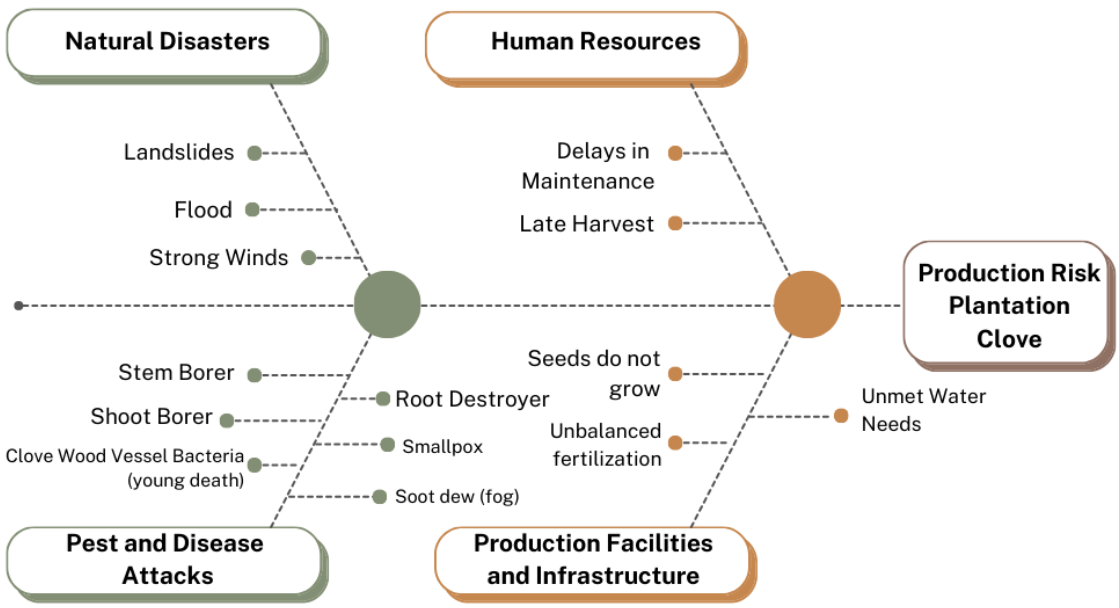


**Figure 3.** Fishbone diagram of clove production risk

After conducting extensive interviews with farmers, tabulating the data and then analyzing it using triangulation methods, we identified 14 different causes of production risks, which we then categorized into four main groups: (1) natural disasters, (2) human resource limitations, (3) pest and disease pressures, and (4) inadequate production facilities and infrastructure. The natural disaster category includes landslides, floods, and strong winds. Human resource-related risks comprise delays in plant maintenance and insufficient knowledge of proper plant management. Pest and disease pressures encompass stem borers, shoot borers, root destroyers, bacterial infection (young plant death), smallpox, and sooty dew (fog). Finally, facility and infrastructure risks include poor seed germination, improper fertilizer application, and insufficient water availability. Figure 3 presents the complete fishbone diagram analysis of these clove plantation production risks.

Natural disasters

Clove plantations in the study area are predominantly located in hilly terrain characterized by high rainfall patterns. Farmer interviews revealed that frequent natural disasters - particularly floods, landslides, and strong winds - significantly impact clove production through both direct damage to plants and long-term soil degradation (Table 2). These extreme weather events and geological hazards disrupt cultivation cycles, damage infrastructure, and reduce overall yields.

**Table 2.** Causes of production risk of natural disaster groups in clove plantations in Gunung Talang District.

| Code | Causes of production risk | Roots/ causative factors of production risk | Farmer | % |
|---|---|---|---|---|
| A1 | Landslides | 1. High rainfall | 3 | 27.27% |
| | | 2. Land cultivation is on the slope | 8 | 72.73% |
| | **Total** | | **11** | **100%** |
| A2 | Flood | 1. Poor drainage | 2 | 25.00% |
| | | 2. High rainfall in a short period | 6 | 75.00% |
| | **Total** | | **8** | **100%** |
| A3 | Strong Winds | 1. Transitional season *(Indonesian: pancaroba)* | 17 | 100% |
| | **Total** | | **17** | **100%** |

Landslide risks were reported by 11 farmers, with medium intensity occurring 1-2 times annually. The primary contributing factors include excessive rainfall (27.27% of cases) and improper slope cultivation without conservation measures (72.73%). These landslides cause significant damage to clove plants, typically destroying 3-10 trees per incident. The impacts are particularly severe as they reduce both immediate production through tree loss and long-term productivity through root system damage that requires extended recovery periods. These findings align with Prayoga et al., (2022), who demonstrated that environmental instability substantially affects plantation crop yields. Despite the hilly terrain, flood intensity remains relatively low due to effective drainage systems and sufficient vegetative cover for water absorption. However, flooding persists as a seasonal threat, primarily during heavy rainfall (75% of cases) or when drainage systems become blocked (25%). Notably, strong winds represent the most severe natural hazard, with 56.67% of farmers reporting high incidence rates (>3 occurrences yearly), particularly during seasonal transitions or *pancaroba* seasons. These winds cause extensive physical damage including broken branches and stem damage in young plants, while also reducing potential yields through premature flower drop.

Human resource factors

Human resource availability plays a critical role in clove production outcomes (Table 3). For Gunung Talang District farmers, two primary labor-related risks emerge: delays in essential maintenance activities and untimely harvesting operations. These workforce challenges directly impact both crop quality and yield quantities.

Delays in clove plant maintenance represent a critical risk factor significantly impacting production outcomes. Our survey reveals that 70% of farmers postpone essential maintenance due to non-implementation of recommended Standard Operating Procedures (SOPs), while 30% attribute maintenance delays to treating clove farming as a secondary occupation. The implementation of proper SOPs - including weeding, fertilization, pruning, and pest control - proves vital for maintaining plant health and preventing pest/disease infestations (Basri et al., 2024). However, most Gunung Talang District farmers fail to fully adopt these protocols. For instance, while weeding should occur 3-4 times annually for optimal results, most farmers perform this activity only once yearly, creating favorable conditions for pest and disease proliferation through uncontrolled weed growth.

**Table 3.** Causes of production risks of human resource groups in clove plantations in Gunung Talang District.

| Code | Causes of production | Roots/ causative factors of production risk | Farmer | % |
|---|---|---|---|---|
| B1 | Delays in maintenance | 1. Lack of SOP implementation | 21 | 70.00% |
| | | 2. Not a primary job | 9 | 30.00% |
| | **Total** | | **30** | **100%** |
| B2 | Late harvesting | 1. Labor limitations during harvest | 8 | 36.36% |
| | | 2. Unfavorable weather | 3 | 13.64% |
| | | 3. Not Harvested simultaneous | 11 | 50.00% |
| | **Total** | | **22** | **100%** |

All respondent farmers in the district maintain clove cultivation as a secondary activity alongside primary occupations like rice farming, trading, or other businesses. This divided focus results in severe time and labor constraints for proper plantation management, ultimately reducing yields and increasing production risks (Saputro et al., 2024). Harvest timing presents another significant challenge, with farmers reporting multiple causes of delays: limited labor availability (36.36%), unfavorable weather conditions (13.64%), and non-synchronous plant maturation (50%). The typical reliance on just 1-2 workers per farm leads to prolonged harvest periods that compromise crop quality (Sibaki et al., 2023). Adverse weather events like heavy rainfall or strong winds further disrupt harvest schedules, while inconsistent plant development across age groups prevents simultaneous harvesting, causing economic losses through suboptimal harvest timing.

Pest and disease pressures

This research identified six major biological threats to clove plantations in Gunung Talang District: (1) stem borers, (2) shoot borers, (3) root destroyers, (4) bacterial vascular disease, (5) clove pox, and (6) sooty mold. These pests and diseases collectively represent one of the most severe production risk categories, each causing distinct damage patterns and yield reductions (Table 4).

**Table 4.** Causes of production risk of pest and disease attack groups in clove plantations in Gunung Talang District.

| Code | Causes of production risk | Roots/ causative factors of production risk | Farmer | % |
|---|---|---|---|---|
| C1 | Stem borer | 1. Suboptimal garden management | 19 | 63.33% |
| | | 2. Delay in pest detection | 11 | 36.67% |
| | **Total** | | **30** | **100%** |
| C2 | Shoot borer | 1. Lack of pruning | 15 | 78.90% |
| | | 2. Uneven watering | 4 | 21.10% |
| | **Total** | | **19** | **100%** |
| C3 | Root destroyer | 1. Lack of land cleanliness | 23 | 76.67% |
| | | 2. Poor management of young plants | 7 | 23.33% |
| | **Total** | | **30** | **100%** |
| C4 | Clove wood vessel bacteria | 1. Improper selection of seedlings | 12 | 40.00% |
| | (young death) | 2. Lack of disease control | 18 | 60.00% |
| | **Total** | | **30** | **100%** |
| C5 | Smallpox | 1. High rainfall and humidity | 6 | 75.00% |
| | | 2. Planting plants that are too dense | 2 | 25.00% |
| | **Total** | | **8** | **100%** |
| C6 | Soot dew (fog) | 1. High humidity and rainfall | 17 | 56.67% |
| | | 2. Lack of control knowledge | 13 | 43.33% |
| | **Total** | | **30** | **100%** |

Stem borer infestations pose a serious threat to clove plants, with larvae tunneling into stems and gradually killing branches, potentially leading to complete tree mortality if left uncontrolled. Our findings identify two primary causes: suboptimal garden management (63.33% of cases) and delayed pest detection (36.67%). Poor management practices like irregular maintenance increase vulnerability, while failure to prune or remove infected branches enables borer populations to expand (Basri et al., 2024). These pests typically enter through small stem openings and can cause rapid damage if not detected early. As Kulendeng et al (2021) emphasize, timely pest detection is critical for preventing extensive plant damage, with inadequate monitoring being the main reason for delayed identification.

Shoot borers represent another significant threat, damaging developing shoots and reducing yields. The primary contributing factors are lack of pruning (78.9%) and uneven watering (21.1%). Irregular pruning results in fragile branches that are particularly susceptible to infestation, while inconsistent watering weakens shoots, making them more vulnerable. Proper pruning not only enhances plant health but also reduces pest habitats and improves air circulation (Basri et al., 2024). As Prayoga et al., (2022) note, uneven water distribution induces plant stress, further decreasing resistance to shoot borer attacks.

Caused by soil-borne root pests, locally known as "lundi" pests primarily affects young, vulnerable plants, with poor land cleanliness (76.67%) and inadequate young plant management (23.33%) being the main causes. Weed-infested fields with accumulated plant debris create ideal breeding conditions for these and other pests (Hariance et al., 2023). Young plants require careful attention to soil preparation and nutrition, with poor practices like improper fertilization or soil compaction exacerbating root vulnerability (Kinangsih et al., 2022).

Bacterial infections causing young plant death stem primarily from improper seedling selection (40%) and insufficient disease control (60%). Using contaminated seedlings from infected trees significantly increases transmission risk (Maharani et al., 2024). Effective prevention requires disease-free seedlings from healthy stock combined with proper fungicide application and other control measures.

Fungal diseases present additional challenges (1) Leafpox, caused by fungal infection, thrives under high rainfall/humidity (75% of cases) and overcrowded planting (25%), with proper spacing being crucial for reducing humidity and infection risk (Luthfi et al., 2018). (2) Sooty mold flourishes in humid conditions (56.67%) and is exacerbated by farmers' limited control knowledge (43.33%). These biological threats collectively arise from interrelated factors including management practices, farmer knowledge, environmental conditions, and cultivation techniques.

<u>Production facilities and infrastructure</u>

The study identified three key production risks related to facilities and infrastructure in Gunung Talang District's clove cultivation: (1) failure of seeds to germinate properly, (2) improper or unbalanced fertilizer application, and (3) inadequate water supply for irrigation needs. These infrastructure-related challenges significantly impact clove production outcomes by affecting plant establishment, growth, and development.

Poor seed germination reduces plant density and potential yields from the outset, while improper fertilization practices lead to nutrient deficiencies or toxicities that compromise plant health. Insufficient water availability during critical growth stages further exacerbates these challenges, particularly in the district's hilly terrain where irrigation infrastructure may be limited. Together, these factors create substantial barriers to achieving optimal clove production levels in the region.

The study identified two primary causes of seed germination failure: poor seed quality (53.33% of cases) and extreme weather conditions (46.67%). Substandard seeds significantly reduce clove plant establishment success rates, as diseased or weak seeds produce vulnerable seedlings prone to pest and disease infestation. Lawolo et al. (2022) emphasize that rigorous seed selection is crucial, as seeds from infected or unhealthy parent trees substantially increase growth failure risks. Concurrently, climate extremes, including prolonged droughts and excessive rainfall, disrupt normal germination processes. Kinangsih et al. (2022) demonstrate that climate change has intensified these weather extremes, necessitating more climate-aware planting schedules and adaptive cultivation techniques from farmers.

**Table 5.** Causes of production risk of production facilities and infrastructure groups in clove plantations in Gunung Talang District.

| Code | Causes of production risk | Roots/ causative factors of production risk | Farmer | % |
|---|---|---|---|---|
| D1 | Seeds do not grow | 1. Poor seed quality | 16 | 53.33% |
| | | 2. Climate and extreme weather | 14 | 46.67% |
| | **Total** | | **30** | **100%** |
| D2 | Unbalanced fertilization | 1. Capital limitations | 19 | 63.33% |
| | | 2. Unclear use of fertilizer dosage | 11 | 36.67% |
| | **Total** | | **30** | **100%** |
| D3 | Unmet water needs | 1. Farmers rely only on rainwater | 30 | 100% |
| | **Total** | | **30** | **100%** |

*Fertilization issues*

Unbalanced fertilization stems from two key factors: capital constraints (63.33%) and improper dosage knowledge (36.67%). Financial limitations prevent farmers from purchasing adequate quantities of quality fertilizers, compromising their ability to meet plants' nutritional requirements. As Baroroh et al. (2021) note, this often forces reliance on inexpensive, low-grade fertilizers. Furthermore, many farmers struggle with appropriate application rates, leading to either nutrient deficiencies or toxic excesses. Maharani et al. (2024) highlight that such imbalances result in stunted growth, increased pest/disease vulnerability, and reduced yields.

*Water management challenges*

Complete dependence on rainfall (100% of cases) represents the sole cause of irrigation deficiencies in the study area. While cloves typically thrive under natural precipitation, extended dry spells and climate variability increasingly cause water shortages that disrupt plant metabolism and photosynthesis (Nurliana et al., 2024). This underscores the need for supplemental irrigation systems like wells or rainwater harvesting to ensure consistent water availability.

Human resource–related risks, particularly maintenance delays (B1) (Table 3), are closely linked to production facility risks, especially unbalanced fertilization (D2) (Table 5). Field evidence indicates that maintenance delays are primarily caused by weak implementation of standard operating procedures (SOPs) in clove cultivation, including fertilization schedules, dosage determination, and application timing. The absence of clear and consistently applied SOPs leads to inadequate technical guidance for farmers in assessing crop nutrient requirements at different growth stages.

This failure in SOP implementation directly results in incorrect fertilization practices, where farmers tend to reduce fertilizer dosage or apply inappropriate fertilizer types. Over time, such practices reduce soil fertility and plant health, while simultaneously increasing production costs without proportional yield improvement. Consequently, repeated fertilization inefficiencies constrain farmers' financial capacity to purchase higher-quality fertilizers in subsequent production periods. This indicates that maintenance delays, as a human resource issue, function as a triggering factor that amplifies facility and infrastructure-related production risks.

*indicative risk prioritization based on severity and occurrence*

Although this study primarily aims to identify the sources of production risk in clove plantations, an indicative quantitative prioritization was conducted to strengthen the analytical linkage between risk identification and management implications using the explanatory analysis. This prioritization does not employ the Failure Mode and Effect Analysis (FMEA) method, but rather a simplified ranking approach based on Severity (S) and Occurrence (O) values derived from farmer survey data (Table 6).

Severity reflects the average magnitude of production loss experienced by farmers when a particular risk occurs, measured using a five-point ordinal scale based on the affected number of clove trees. Occurrence represents the frequency of risk events experienced by farmers within the observed production period. Both parameters were calculated as mean values from structured interviews with clove farmers in Gunung Talang District, following the assessment framework applied in the underlying thesis research.

To indicate the relative importance of each risk source, a Priority Score was calculated as the product of Severity and Occurrence (S × O). This score provides a quantitative indication of risk criticality while remaining consistent with the study's scope, which focuses on risk identification rather than comprehensive risk evaluation.

**Table 6.** Indicative prioritization of clove production risk causes based on severity and occurrence

| Code | Risk Cause | Severity (S) | Occurrence (O) | Priority score (S × O) |
|---|---|---|---|---|
| A1 | Landslides | 1.45 | 1.40 | 2.03 |
| A2 | Floods | 1.25 | 1.33 | 1.66 |
| A3 | Strong winds | 1.24 | 2.40 | 2.98 |
| B1 | Delays in maintenance | 2.00 | 4.00 | 8.00 |
| B2 | Delayed harvesting | 1.45 | 2.50 | 3.63 |
| C1 | Stem borer pests | 2.73 | 4.00 | 10.92 |
| C2 | Shoot borer pests | 1.21 | 2.00 | 2.42 |
| C3 | Root-damaging pests | 1.93 | 3.77 | 7.28 |
| C4 | Vascular bacterial disease | 1.77 | 4.00 | 7.08 |
| C5 | Leaf pox disease | 1.13 | 1.37 | 1.55 |
| C6 | Sooty mold | 1.20 | 2.63 | 3.16 |
| D1 | Poor seed germination | 1.47 | 4.00 | 5.88 |
| D2 | Unbalanced fertilization | 1.87 | 3.43 | 6.41 |
| D3 | Insufficient water availability | 1.83 | 2.63 | 4.81 |

The prioritization results indicate that biological risks, particularly stem borer infestation (C1), exhibit the highest priority score, reflecting both high severity and frequent occurrence. This finding is consistent with farmers' reports that pest attacks cause irreversible damage to clove trees and significantly reduce long-term productivity. The severity score of 2.73 indicates that stem borer pests represent a moderate to high level of impact on the farming system, as infestations can substantially reduce crop vigor and yield if not properly controlled. This level of severity suggests that damage caused by stem borers may directly impact plant productivity and, in some cases, result in economic losses for farmers. The occurrence value of 4.00 reflects a high frequency of incidence, indicating that stem borer attacks are relatively common and constitute a recurring challenge in the study area. As a result of the combination of considerable impact and high likelihood, the priority score of 10.92 categorizes stem borer pests as a high-priority risk. This finding implies that the threat requires immediate attention and targeted management strategies. Effective pest control measures, regular field monitoring, and the adoption of integrated pest management practices are therefore essential to reduce both the frequency and severity of infestations, thereby safeguarding crop productivity and farm sustainability

Human resource–related risks, notably delays in maintenance (B1), also show high priority scores, underscoring the critical role of timely field management practices. Such delays often lead to cascading effects, including ineffective fertilization schedules and delayed pest control, which further exacerbate production losses. Facility-related risks such as unbalanced fertilization (D2) and insufficient water availability (D3) also rank relatively high, highlighting structural limitations in plantation inputs and infrastructure.

Natural hazards such as strong winds (A3) demonstrate moderate severity but recurring occurrence, justifying their inclusion as important risk factors that require preventive mitigation measures. Overall, the quantitative prioritization strengthens the fishbone-based causal analysis and provides empirical justification for focusing risk management efforts on a limited number of dominant production constraints.

*Production risk management framework*

Following risk identification, we developed management strategies in collaboration with Gunung Talang District Agricultural Extension Workers, incorporating literature review and local capacity assessment. Kountur (2008) categorizes risk management into preventive and mitigation approaches. For clove plantations in the study area, we propose the evidence-based strategies, as shown in Table 7.

**Table 7.** Production risk control strategies in clove plantations in Gunung Talang District

| No | Source of risk | Preventive strategies | Mitigation strategies |
|---|---|---|---|
| 1 | Natural disasters | Planting of buffer vegetation (Risk avoidance) | |
| 2 | Human resources | Training and counseling to farmers (Risk control) | Strengthening the work system of farmer groups (Risk retention) |
| 3 | Pest and disease attacks | Selection of superior seedlings resistant to pests and diseases (Risk avoidance)<br><br>Implementation of land SOP (Risk control) | Pest control with biological agents (Risk control)<br><br>Use of plant-based pesticides (Risk control) |
| 4 | Production facilities and infrastructure | Provision of subsidies and access to credit for farmers (Risk avoidance) | Provision of reserve funds for farmer groups (Risk retention) |

Preventive strategies

Preventive strategies aim to reduce the likelihood of production risks by emphasizing proactive measures implemented before risk occurrence. One key approach is the planting of buffer vegetation (Risk Avoidance), such as vetiver, Axonopus compressus (carpet grass), or bamboo, which is effective in preventing landslides on hilly terrain like Mount Talang. These areas are highly vulnerable due to steep slopes and high rainfall intensity. Buffer plants possess strong root systems that stabilize soil structure, reduce surface runoff, and maintain soil quality. Virgota et al. (2022) report that vetiver can reduce erosion by up to 85%, making it particularly suitable for landslide-prone plantations. In addition, bamboo provides supplementary economic benefits through harvestable products.

 

Farmer training and counseling programs (Risk Control) constitute another critical preventive measure. Most farmers in Gunung Talang rely on traditional knowledge, resulting in limited understanding of modern cultivation Standard Operating Procedures (SOPs). The study indicates that approximately 70% of farmers experience maintenance delays due to insufficient technical information. Structured training can improve farmers' knowledge of land sanitation, balanced fertilization, and appropriate pesticide application. Listyanto et al. (2023) demonstrate that farmer training increases adoption of proper cultivation techniques by 30%, leading to higher yields and reduced production risks.

Risk avoidance strategies by using superior and pest-resistant seeds are also essential for preventing early plant mortality and disease outbreaks caused by uncertified seedlings. High-quality seeds not only increase yield potential by up to 40%, but also exhibit greater resistance to humidity-related diseases such as sooty mold. Government or cooperative-led seed distribution programs can ensure equitable farmer access to certified planting materials (Akbar et al., 2023).

The implementation of land management SOPs (Risk Control), including scheduled fertilization, weeding, and pest monitoring, enables early detection of pest infestations and plant diseases. Basri et al. (2024) report that consistent SOP application can improve productivity by up to 20%, which is particularly important under Gunung Talang humid conditions. Furthermore, input subsidies and access to agricultural credit (Risk Avoidance) help farmers overcome financial constraints in acquiring quality fertilizers and pesticides, while supporting irrigation development during dry seasons (Akbar et al., 2023).

Mitigation strategies

Mitigation strategies focus on reducing the impacts of risks that cannot be fully avoided. Strengthening risk retention strategies with farmer group institutions enhances collective capacity to address challenges such as labor shortages, rising input costs, and post-disaster recovery. Minarsih and Waluyati (2019) show that well-organized farmer groups can increase farming efficiency by up to 25%. In Gunung Talang, farmer groups facilitate coordinated harvesting, collective input procurement, and access to government programs such as subsidies and crop insurance.

Biological pest control (Risk Control) represents an environmentally friendly mitigation approach for reducing losses caused by severe pest infestations. Agents such as *Trichoderma* spp. and *Beauveria bassiana* are effective in controlling stem borers and other major pests without leaving chemical residues. Rachmawatie et al. (2022) report that *Trichoderma* not only suppresses pest populations but also improves soil fertility, making it suitable for pest-prone clove plantations.

Botanical pesticides (Risk Control), including neem leaf extract and lemongrass-based formulations, offer cost-effective alternatives to synthetic pesticides. Haerul et al. (2016) demonstrate their effectiveness in controlling shoot borers when applied repeatedly and correctly. Successful implementation requires farmer training in proper preparation and application methods.

Natural disaster risk mitigation must also include post-event response mechanisms in addition to preventive measures. Since hazards such as landslides, floods, and strong winds cannot be entirely prevented, adaptive mitigation strategies are essential. The establishment of a Group Reserve Fund provides financial resources specifically allocated for post-disaster recovery. These funds can be used for emergency replanting, replacement of damaged plants, rehabilitation of drainage systems, and restoration of damaged production facilities. Furthermore, the development of a group-level emergency response plan, including role allocation and prioritization of land recovery activities, is critical for minimizing economic losses and accelerating production recovery. The integration of preventive and post-disaster mitigation measures strengthens the overall resilience of clove production systems.

 

## CONCLUSIONS

This study demonstrates that production risks in clove farming in Gunung Talang District are driven by interconnected factors related to natural hazards, human resource limitations, pest and disease pressure, and inadequate production infrastructure. The application of the fishbone diagram highlights that production vulnerability arises from the interaction of multiple root causes rather than isolated factors, providing a structured approach for identifying key sources of risk in clove production systems. The findings suggest that risk mitigation efforts should prioritize strengthening farmers' technical capacity, improving access to certified and pest-resistant planting materials, and enhancing land and water management practices appropriate for rain-fed and sloped plantations. Strengthening farmer group institutions is also important to improve collective resilience against recurring risks. Nevertheless, the qualitative and localized nature of this study limits risk quantification and broader generalization. Future research is therefore recommended to integrate fishbone-based risk identification with quantitative approaches such as Failure Mode and Effect Analysis (FMEA) to enable more precise risk prioritization and scalable risk management across different agro-ecological regions.

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