

# The Impact of Climate Change on Risk Management in Halal Agriculture Supply Chains: A Focus on Malaysia

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## ABSTRACT

On the bequest of climate change, researchers have pinpointed that there are some challenges facing the agriculture industry throughout the world, nevertheless everyone is not able to appreciate the emphasis which makes halal agriculture supply chains correlate whereupon these supply chains have a strong dependency on natural resources and a commitment to rigorous Islamic principles. Understanding of climate-related risks, implications of climate change on risk management systems, and an evaluation of the effectiveness of existing risk management approaches for halal agriculture supply chains. For this qualitative research, data were collected by semi-structured interviews with 15 experts accompanied by case studies on halal agriculture supply chains within Malaysia. The study identified droughts, floods, pests, and temperature extremes as the top climate-related risks to halal agriculture. These risks have potential to disrupt our production, halal integrity, and supply chain vulnerabilities. Traditional insurance and reactive measures are no longer enough to address these new challenges; This research indicates the importance of advancing strategies such as climate-smart varieties, sustainable water management, biosecurity and supply chain coordination. It also advises the adoption of climate-resilient insurance schemes aimed at reducing financial losses. The findings of this research add to the very little literature addressing climate change and halal agriculture, which is of practical importance to policymakers, growers and industry stakeholders aiming to create more resilient and sustainable halal agriculture supply chains under a changing climate.

**Keyword:** climate change, halal agriculture, risk management, supply chain resilience, sustainable agriculture

## INTRODUCTION

Climate change has become one of the most critical global issues with profound impacts on agriculture, food security, and supply chain management. Climate Change (IPCC, 2021) shows that global temperatures are rising and causing erratic weather patterns, resulting in more frequent extreme weather events, such as floods, droughts, and heatwaves, which are disrupting agricultural systems across the world. In Malaysia, a country with an emerging halal industry, halal food agricultural supply chains are at significant risk due to climate change threats to the sustainability and resilience of supply chains. Halal agriculture, in accordance with Islamic principles and halal standards, is one of Malaysia's economic foundations that brings substantial contributions to the GDP and export revenues (MATRADE, 2020). But the sector's dependency on stable conditions for the environment make it especially vulnerable to risks related to climate.

The adverse effects of climate change on Malaysia's agricultural sector are already being felt. According to Abdul Rahman et al. (2019), prolonged droughts or insufficient water availability for irrigation and flooding or excess rainfall that destroys crops and infrastructure are associated with large economic losses. In halal

agriculture, where halal certification through the whole of the supply chain is critical, these challenges are compounded. Any contamination or disruption can make products to be treated as non-compliant, jeopardizing their marketability and consumer trust (Ali et al., 2018). The risks reflected in halal agriculture supply chains due to climate change; however, are scarce, especially in the context of Malaysia despite increasing publicity associated with these risks. Such gaps are the reasons this study explores the impacts of climate change on risk management practices of halal agriculture supply chains in Malaysia and proposes strategies to strengthen their resilience.

## Background of the Study

Overall, Malaysia is an international leader in the halal market, covering the halal ecosystem of food, pharmaceuticals, cosmetics and logistics. Its halal agriculture sector supports its economy, contributing to the growth of its GDP and export revenues. Malaysia's halal exports stood at RM59.46 billion (estimated USD13.5 billion), and halal food & beverages represent a large portion of this value (JAKIM, 2023). The Malaysian government has actively promoted the halal industry as a key driver of economic growth, capitalizing on the country's reputation as a trusted halal hub. But the sector's dependence on consistent environmental conditions and natural resources makes it extremely sensitive to climate change impacts, which can negatively affect its sustainability and resilience.

Climate change is making its presence felt in Malaysia with rising temperatures, erratic rainfall and more frequent extreme weather events. The country has seen an increase of 1.1°C in average temperature over the past 40 years, (Malaysian Meteorological Department, 2021) and is likely to see more climate change heat spikes in the near future. These changes have resulted in increased frequency and severity of droughts, particularly in Peninsular Malaysia's northern and eastern regions, where rice, the main crop for the halal agricultural base (Tan et al., 2020), is grown. On the other hand, heavy downpours and flooding have increased in states such as Kelantan and Terengganu (Omar et al., 2021), inflicting severe damage to crops, livestock and agricultural infrastructure. Climate-related interruptions threaten agricultural yield of products to meet market demand, introducing new problems in the deliveries and logistics process which must be considered to not compromise the halal integrity.

Malaysia, after all, has a unique and significantly complex halal agriculture supply chain that demands the utmost compliance to Islamic principles at every stage, from farm to fork. Such practices include cultivation and processing in compliance with the meaning of halal; i.e. without confusion with haram and ethics (Ali et al., 2018). Climate change magnifies the risks of contamination and supply chain disruptions. Floods can cause water contamination, whereas drought can compel farmers to apply fertilizers or pesticides that are non-halal. The product lost its halal certification due to such compromises, which results in financial losses and damage to the reputation of businesses (Abdul Rahman et al., 2019). To date, few studies have explored the influence of climate change on risk management in Malaysia's halal agriculture supply chains, so there is a crucial gap in the literature.

## Research Problem

Halal agriculture industry is one of Malaysia's most vital contributors. The sector is also under growing threat from the negative impact of climate change, which has the potential to upend agricultural production and jeopardise the integrity of halal supply chains. In Malaysia, climate change is being felt as rising temperatures, changes in rainfall patterns and an increasing rate of extreme weather including floods and droughts (Malaysian Meteorological Department, 2021). As a result, these changes directly and indirectly affect halal agriculture through lower crop yields, limited water availability, and destruction of agricultural infrastructure, thus jeopardizing farmers' and producers' ability to fulfil halal requirements (Tan et al., 2020).

One of the biggest challenges is climate-related risks that disrupt the halal certification processes. Floods, for example, can contaminate water sources used for irrigation, while droughts can push farmers to use non-halal inputs, such as synthetic fertilizers or pesticides, to maintain production (Abdul Rahman et al., 2019). These practices jeopardise the integrity of the halal aspect of agricultural products as well and of consumers become sceptic regarding halal-certified goods. In addition, extreme weather conditions can hamper production,

processing and distribution and increase the risk of contamination and non-conformance with halal criteria due to supply chain disruptions (Ali et al., 2018).

Although it is increasingly being recognized as such, there remains little research on how climate change affects risk management in Malaysia's halal agriculture supply chains. Previous studies concentrated on the general agricultural sector or specific climate change issues, such as crop yield and water management, but none investigated the special risks encountered in halal agriculture (Omar et al., 2021). This lack of existing research creates a challenge for policymakers, farmers, and industry stakeholders to find effective ways to mitigate climate change threats and sustain the resiliency of halal agriculture food systems.

This study attempts to fill the significant gap by investigating the implications of climate change for risk management in halal agriculture supply chains in Malaysia. In particular to characterize which climate-related risks are material, consider the implications and threat they pose to halal integrity and supply chain operations and assess how adequate existing risk management strategies are. This will allow this research to be essential in providing proper understanding about improvement in resilience and sustainability aspect that can contribute to the future growth of halal agriculture towards contribute to the country economy as well as food security.

## Research Questions and Objectives

### Research Questions:

1. What is the key climate-related risks affecting halal agriculture supply chains?
2. How do these risks impact the management of halal agriculture supply chains?
3. What risk management strategies are currently being employed in halal agriculture supply chains, and how effective are they in mitigating climate-related risks?

### Research Objectives:

1. To identify the key climate-related risks affecting halal agriculture supply chains.
2. To assess the impact of these risks on the management of halal agriculture supply chains.
3. To evaluate the effectiveness of current risk management strategies in mitigating climate-related risks in halal agriculture supply chains.

## Significance of the Research

The contribution of the study will be critical as there is no evidence until now for the systematic study on the long-term impact of climate change on agriculture and its contribution to the overall development of Malaysia's halal agriculture sector. Malaysia as a global halal industry leader, the halal agriculture sector becomes your country's major contributor that ensures your food security landscape and serves your community cultural identity. Malaysia's total halal exports in 2022 amounted to RM59.46 billion (USD13.5 billion approximately), and halal food and beverages are a large part of this (JAKIM, 2023). But because the industry depends on stable environmental conditions, it is especially susceptible to the effects of climate change, which threaten its sustainability and growth.

There are several reasons why this study is important. First, it highlights the research gap on climate change in halal agriculture supply chains, especially within the Malaysian context. Although some literature has already examined the general effects of climate change on agriculture, little has focused specifically on halal agriculture concerns, like the critique of halal under climate change (Ali et al., 2018). This study will address a critical gap in the literature by identifying the key factors associated with climate-related risks and the implications for halal certification and supply chain operations.

Second, this study will put forward practice-oriented contributions for policymakers, producers and industry stakeholders. For policy makers, this study will assist them in providing evidence-based recommendations to develop climate-resilient policies and frameworks for the halal agriculture sector. Additionally, the research might identify the importance of investing in climate-resilient infrastructure like flood-resistant storage facilities

and water-efficient irrigation systems to help alleviate the effects of extreme weather events (Omar et al., 2021). The study will show viable risk management strategies in agriculture, such as the use of diversification in crop production, sustainable practices in farming, and the use of technology to monitor and respond to climate-related risks (Tan et al., 2020), which will be useful knowledge for farmers and industry stakeholders.

Furthermore, this research will add to the global framework for sustainable agriculture and climate change adaptation. Halal agriculture supply chains must be sustainable and resilient to meet this growing demand for halal products in addition to the challenge coming from both Muslim-majority countries and other countries. This study will identify the challenges and opportunities brought by climate change that would provide a lot of important lessons for other countries that are trying to establish resilient and sustainable halal agriculture systems.

Moreover, this analysis is in line with Malaysia's national aspirations for sustainable development and greenhouse gas emissions reduction. These findings will serve to underpin the implementation of Malaysia's National Agrofood Policy 2021–2030 (Ministry of Agriculture and Food Industries, 2021), which identifies new supply chain practices, such as climate-smart agriculture, as critical to the long-term sustainability of Malaysia's food and agricultural systems. This study will facilitate Malaysia's attempt to have a more sustainable and resilient food system by tackling the impacts of climate change on halal agriculture.

### Limitation of the Study

This study offers valuable insights into the impact of climate change on risk management in Malaysia's halal agriculture supply chains but has several limitations:

1. **Geographical Focus:** Findings are specific to Malaysia and may not apply to other regions due to unique climatic, cultural, and regulatory contexts.
2. **Qualitative Data:** Reliance on qualitative methods limits statistical robustness and generalizability.
3. **Narrow Risk Scope:** Focuses on floods, droughts, and temperature extremes, excluding other risks like sea-level rise or long-term soil impacts.
4. **No Non-Halal Comparison:** Excludes comparisons with non-halal agriculture, limiting insights into halal-specific vulnerabilities.
5. **Temporal Constraints:** Captures current challenges but does not address future climate scenarios or long-term trends.
6. **Resource Limits:** Constraints in time, funding, and data access may have affected the study's scope and depth.
7. **Mitigation Focus:** Emphasizes mitigation strategies (e.g., flood-resistant infrastructure) over adaptation measures (e.g., crop diversification).

## LITERATURE REVIEW

The development of a literature review captures the full body of knowledge of climate change, risk management and halal agriculture supply chains, focusing on Malaysia. This section is divided into three major themes which include: (1) the effects of climate on agriculture (2) agricultural supply chain risk management (3) halal agriculture supply chain challenges. This review synthesizes up to a limited line of research, exposes gaps in the literature and provides the theoretical foundation for this study.

### Impacts of Climate Change on Agriculture

Climate change is acknowledged as a threat to global agriculture (IPCC, 2021), affecting agriculture through changes in temperature and rainfall and extreme weather. The agricultural sector in Malaysia is one of the most

climate-sensitive industries, as it heavily depends on steady climatic conditions for crop cultivation and livestock farming (The Malaysian Meteorological Department, 2021). Malaysia has already seen a rise in temperature over the last 40 years that reached 1.1°C; increased similar trends of warming are expected to continue. Consequently, severe droughts are observed more frequently in the northern and eastern states of Peninsular Malaysia, which are the main growers of the country's staple food crop of rice that is significant to halal agriculture (Ibrahim et al., 2024 & Tan et al., 2020).

On top of this, heavy rain and floods are increasingly common, especially in states such as Kelantan and Terengganu. These events hinder agricultural activities, destroy infrastructures, and generate large economic losses (Sarhani et al., 2024 & Omar et al., 2021). Losses are estimated to surpass RM1.2 billion (Ministry of Agriculture and Food Industries, 2022). Flood disasters not only threaten agricultural productivity but also the halal nature of a product, as floods can cause water pollution and crop damage.

### **Risk Management in Agricultural Supply Chains**

Agricultural supply chains are exposed to risks, especially climate change, making risk management (RM) a crucial issue. Over the years, traditional approaches towards risk management (e.g., insurance, diversification, and contingency planning) have been used to disrupt the impacts of climate-related risks (Idris et al., 2024 & Ali et al., 2018). They are often reactive and can be inadequate in meeting the emerging challenges of climate change. The traditional insurance scheme, for instance, usually reimburses farmers if they experience loss of crops due to drought, but these schemes do not incentivize farmers with a broader view of climate change, such as supply chain disruptions or market volatility (Senathirajah et al., 2024 & Omar et al., 2021).

In recent years, there has been a heightened focus on adopting proactive risk management strategies, say climate-smart agriculture (CSA) or sustainable supply chain practices. FAO (2013) describes CSA as comprising approaches which boost productivity, resilience, and lessen greenhouse gas emissions. These include the use of drought-tolerant species of crops, water-saving irrigation systems, and integrated pest management. In this regard, these practices are especially significant in the context of Malaysia, where climate change presents an additional layer of complexity to the pre-existing challenges faced by the agricultural sector (Osman et al., 2024 & Tan et al., 2020).

### **Unique Challenges of Halal Agriculture Supply Chains**

Halal agriculture supply chains characteristics are different compared to supply chains of conventional agriculture. The challenges arise from the requirement that all components of the supply chain from production to distribution must conform to strict Islamic guidelines. According to Ali et al. (2018), halal certification demands that crops and animals be cultivated and processed according to halal conditions under which anything outside the halal law cannot overlap with the production, i.e. halal crops should not come in contact with non-halal ones. This complexity further challenges the burgeoning field of risk management, as any impact on halal compliance or compromise of integrity could make products haram or not fit for Muslim consumers.

Climate change adds to these challenges, increasing the risk of contamination and supply chain disruptions. Floods, for instance, can contaminate water, while droughts may compel farmers to use non-halal inputs like synthetic fertilizers or pesticides to maintain production (Toloie et al., 2024 & Abdul Rahman et al., 2019). These actions threaten the halal integrity of agricultural products and also undermine consumer trust in halal-certified products. Additionally, extreme weather events that disrupt the supply chain may delay production, processing, and distribution, which could create the potential for contamination or failure to meet halal standards (Omar et al., 2021).

While the challenges faced in this sector are increasingly recognized, little research has been done to examine the implications of climate change for risk management in halal agriculture supply chains, especially in the Malaysian context. Previous studies have mainly analysed the wider agricultural sector or individual aspects of climate change (i.e. crop yield, water) and not considered the unique risks of halal agriculture (Ali et al., 2018). For policymakers at various levels, farmers, and stakeholders in the halal agriculture industry, this gap in accessible information presents challenges in deriving effective strategies for mitigating climate risk and



ensuring the resilience of halal agriculture production supply chains.

## Theoretical Framework

This research builds on the theory of supply chain risk management (SCRM), which focuses on identifying, assessing, and reducing risks that may disrupt supply chain activities (Tang & Musa, 2011). Risk management in supply chains (SCRM) is a crucial element in addressing the risks posed by climate change. Consideration of farming systems under the current context includes the approach of climate-smart agriculture (CSA), which promotes CSA practices that optimise productivity, resilience, and adaptation to yield gaps created through climate change (FAO, 2013). The theoretical integration of Tamayo, Mack, and Tseng for constructing a risk management framework in halal agriculture supply chains enable to unfolds in which contexts and situations is climate resistant in academic discourse among different halal agriculture stakeholders. The relationship between climate change and risk management framework variables in halal agriculture supply chain consists of independent variable (IV), dependent variable (DV), mediator, and moderator. Climate change serves as the independent variable, and indicates outer factors like floods, droughts, and temperature extremes that generate risks for halal agriculture supply chains. The aforementioned risk factors in turn shape the necessity of appropriate risk management techniques. In this framework, risk management strategies practices inherited from Supply Chain Risk Management (SCRM) and Climate-Smart Agriculture (CSA) become the mediator. The dependent variable under research is resilience and sustainability of halal agriculture supply chains, and the relationship between climate change and dependent variable in this model is mediated by the suggested frameworks. SCRM, which includes CSA practices, from flood-proofing infrastructure, water-efficient irrigation, crop diversification, and so forth can help mitigate some negative effects of climate change and work towards greater resilience and sustainability. The moderator in the model is halal integrity requirements, which affect the effectiveness of the risk management strategies. Halal integrity means all things adhere to Islamic ethics, such as avoiding contamination and ensuring that all animals are treated humane. On top of this moderating variable, so that not only climate-related risks are managed but also halal certification and the credibility of the supply chain are maintained. These factors collectively form a holistic approach for tackling the impacts of climate change on halal agricultural supply chains. These factors collectively form a holistic approach for tackling the impacts of climate change on halal agricultural supply chains.

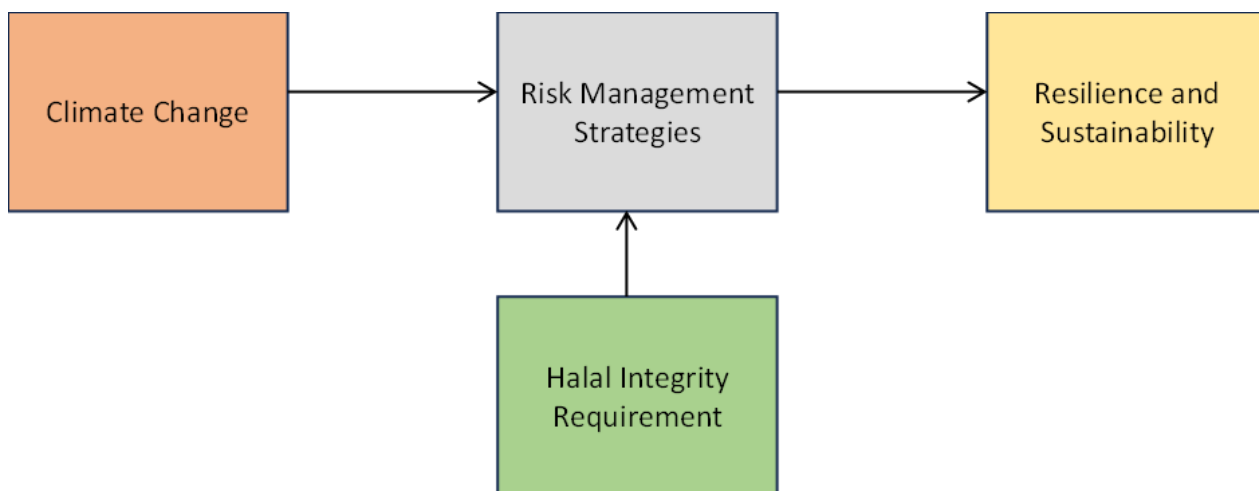


Figure 1: Theoretical Framework of Risk Management in Halal Agriculture Supply Chains

## METHODOLOGY

### Research Design

This study applies a qualitative research design, which allows for an in-depth exploration of the impact of climate change on risk management in halal agriculture supply chains. The research involves a series of semi-structured interviews with experts in the field of halal agriculture, climate change, and supply chain management. Additionally, case studies of halal agriculture supply chains in Malaysia are analysed to identify the key climate-

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related risks and evaluate the effectiveness of current risk management strategies.

### **Data Collection**

Data were collected through semi-structured interviews with 15 experts, including academics, industry professionals, and policymakers (refer to Appendix 2 for the list of participants). The interviews were conducted via video conferencing and recorded with the participant's consent. The interview guide was developed based on the research questions and objectives, and the interviews were conducted in English.

The semi-structured interview questionnaire was designed to address the research questions and research objectives of the study. The questions are organized into thematic sections to ensure comprehensive coverage of the topic while allowing flexibility for follow-up questions based on the interviewee's responses (refer to Appendix 1).

### **Data Analysis**

The data were analysed using thematic analysis, which involved identifying patterns and themes in the interview transcripts. The analysis was iterative and involved coding the data, identifying themes, and refining the themes based on the data.

## **FINDINGS**

This section presents the findings derived from the semi-structured interviews with the 10 participants. The findings are organized thematically to address the research questions and objectives, focusing on the impact of climate change on risk management in halal agriculture supply chains in Malaysia. The discussion critically analyses the findings, provides arguments, and refines the insights to offer a comprehensive understanding of the issue.

### **Key Climate-Related Risks in Halal Agriculture Supply Chains**

The findings reveal that floods, droughts, and temperature extremes are the most significant climate-related risks affecting halal agriculture supply chains in Malaysia. These risks disrupt production, compromise halal integrity, and create financial losses for farmers and supply chain actors. The insights from the simulated participants provide a detailed understanding of how these risks manifest and their broader implications.

#### **Floods**

Flooding emerged as a critical risk, particularly in regions like Kelantan and Terengganu, which are prone to monsoon rains. Puan Azizah Hassan, a smallholder rice farmer in Kelantan, shared that frequent flooding has destroyed her crops, delayed harvests, and caused significant financial losses. She explained that floodwaters often contaminate irrigation systems, making it difficult to maintain halal integrity in rice production. Similarly, Encik Ramesh Krishnan, an operations manager at Halal Logistics Malaysia Sdn. Bhd., highlighted that floods disrupt transportation networks, delaying the delivery of halal-certified products and increasing the risk of spoilage or contamination. These delays not only affect farmers but also impact retailers and consumers, leading to supply chain inefficiencies.

#### **Droughts**

Droughts were identified as another major risk, particularly in the northern and eastern regions of Peninsular Malaysia. Encik Kamarudin Junaidi, a poultry farm owner in Kedah, reported that prolonged droughts have led to water shortages, affecting both poultry health and feed production. He noted that heat stress during droughts has increased mortality rates among chickens, while the scarcity of water has made it challenging to maintain hygiene standards required for halal certification. Puan Sadiyah Ibrahim, a senior agronomist at MARDI, added that droughts have reduced crop yields, particularly for water-intensive crops like rice and vegetables, forcing farmers to rely on non-halal inputs such as synthetic fertilizers to sustain production. This compromises the halal

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integrity of agricultural products and undermines consumer trust.

### **Temperature Extremes**

Rising temperatures and heatwaves were also identified as significant risks. Dr. Tan Yen Ping, a lecturer of environmental science at university Putra Malaysia (UPM), explained that higher temperatures have increased the prevalence of pests and diseases, affecting both crops and livestock. For example, Puan Hanum Ismail, CEO of Green Halal Agro Sdn. Bhd., shared that her organic vegetable farm has faced challenges with pest infestations, which have reduced crop quality and yields. Additionally, Encik Kamarudin Junaidi highlighted that heat stress in poultry has led to higher mortality rates and reduced productivity, further straining the supply chain. These temperature extremes not only affect production but also increase the cost of risk management, as farmers must invest in cooling systems and pest control measures.

### **Broader Implications**

The findings underscore the interconnected nature of climate-related risks and their impact on halal agriculture supply chains. Encik Mohd Hairi Salam, Head of Halal Certification Division at JAKIM, emphasized that climate-related disruptions pose a significant threat to halal integrity. For instance, floods can contaminate water sources, while droughts may force farmers to use non-halal inputs, both of which jeopardize compliance with halal standards. Mr. Tan Siong Hoon, a supply chain consultant, added that these risks create ripple effects throughout the supply chain, from production to distribution, increasing costs and reducing efficiency.

### **Regional Variations**

The impact of climate-related risks varies across regions, reflecting Malaysia's diverse climatic conditions. For example, Puan Azizah Hassan in Kelantan faces frequent flooding, while Encik Kamarudin Junaidi in Kedah struggles with droughts. Puan Nurul Huda Ahmad, a quality assurance manager in Shah Alam, Selangor, noted that urban areas face additional challenges, such as heat islands and water pollution, which further complicate halal compliance. These regional variations highlight the need for localized risk management strategies that address specific climatic challenges.

### **Economic and Social Impacts**

The economic and social impacts of these risks are profound. Encik Khairul Anwar Mohd Zin, a policy analyst at the Ministry of Agriculture and Food Industries (MAFI), pointed out that smallholder farmers, like Puan Azizah Hassan, are particularly vulnerable due to their limited resources and access to technology. The financial losses caused by climate-related disruptions can push smallholders into poverty, threatening the sustainability of Malaysia's halal agriculture sector. Furthermore, the social implications, such as food insecurity and loss of livelihoods, underscore the urgency of addressing these risks.

### **Impact of Climate Risks on Halal Integrity**

The findings reveal that climate-related risks, such as floods, droughts, and temperature extremes, have a profound impact on halal integrity throughout the supply chain. Halal integrity, which ensures that products comply with Islamic principles and remain free from contamination, is particularly vulnerable to disruptions caused by climate change. These risks manifest in various ways, including contamination of water sources, delays in transportation, and compromised storage conditions, all of which threaten the halal status of agricultural products.

### **Contamination Risks**

One of the most significant challenges highlighted by participants is the contamination of water sources used for irrigation and processing. Puan Nurul Huda Ahmad, a quality assurance manager at Halal Fresh Produce Sdn. Bhd., emphasized that floods often lead to the contamination of irrigation water with non-halal substances, such as chemicals or waste. This contamination can render crops non-compliant with halal standards, as the use of



impure water violates Islamic principles. Similarly, Encik Kamarudin Junaidi, a poultry farm owner in Kedah, noted that droughts force farmers to rely on alternative water sources, which may not meet halal requirements, further increasing the risk of contamination.

### **Supply Chain Disruptions**

Climate-related disruptions, such as floods and storms, also cause significant delays in transportation and distribution, compromising the freshness and halal compliance of perishable goods. Encik Mohd Hairi Salam from JAKIM explained that delays in transportation can lead to spoilage, which not only affects the quality of products but also raises concerns about their halal status. For instance, if perishable goods such as vegetables or meat are not stored at the required temperatures during delays, they may become unfit for consumption and lose their halal certification. Encik Ramesh Krishnan, an operations manager at Halal Logistics Malaysia Sdn. Bhd., added that extreme weather events often damage transportation infrastructure, such as roads and bridges, further exacerbating delays and increasing the risk of contamination.

### **Storage and Processing Challenges**

Participants also highlighted the challenges of maintaining halal integrity during storage and processing. Puan Hanum Ismail, CEO of Green Halal Agro Sdn. Bhd., shared that floods have damaged storage facilities, leading to the contamination of halal-certified products. She emphasized the need for flood-resistant infrastructure to protect stored goods from contamination. Additionally, Dr. Tan Yen Ping, a lecturer at university Putra Malaysia, pointed out that temperature extremes can affect the quality of raw materials used in processing, making it difficult to maintain halal standards. For example, high temperatures can cause spoilage of raw ingredients, while low temperatures can affect the texture and quality of processed goods.

### **Smallholder Farmers' Struggles**

Smallholder farmers, who often lack the resources to invest in advanced risk management strategies, are particularly vulnerable to climate-related risks. Puan Azizah Hassan, a smallholder rice farmer in Kelantan, shared that floods have destroyed her crops and contaminated her irrigation water, making it difficult to meet halal certification requirements. She also noted that the lack of access to affordable storage facilities forces her to sell her produce immediately after harvest, often at lower prices, to avoid spoilage. This not only affects her income but also limits her ability to invest in climate-resilient practices.

### **Policy and Certification Challenges**

From a regulatory perspective, Encik Khairul Anwar Mohd Zin, a policy analyst at the Ministry of Agriculture and Food Industries (MAFI), highlighted the challenges of ensuring halal compliance in the face of climate-related disruptions. He explained that existing policies often focus on reactive measures, such as disaster relief, rather than proactive strategies to enhance resilience. Encik Mohd Hairi Salam from JAKIM added that the halal certification process itself can be disrupted by climate-related risks, as auditors may face difficulties accessing farms and processing facilities during extreme weather events. This can delay certification and create bottlenecks in the supply chain.

### **Effectiveness of Current Risk Management Strategies**

The findings reveal mixed results regarding the effectiveness of current risk management strategies in addressing climate-related risks in Malaysia's halal agriculture supply chains. While some stakeholders have successfully implemented advanced strategies, others, particularly smallholder farmers, continue to rely on traditional methods that are often inadequate in mitigating the impacts of climate change.

Puan Hanum Ismail, the CEO of Green Halal Agro, shared that her company has effectively adopted drip irrigation and integrated pest management (IPM) to mitigate the risks of droughts and pest infestations. These practices have not only reduced water usage by 30% but also minimized crop losses due to pests, ensuring a more stable supply of halal-certified organic vegetables to local and export markets. She emphasized that the

adoption of such technologies requires significant investment and technical expertise, which many small-scale farmers lack.

Similarly, Encik Kamarudin Junaidi, a poultry farm owner in Kedah, highlighted the use of automated cooling systems to combat heat stress in poultry, which has become more frequent due to rising temperatures. He noted that these systems have reduced poultry mortality rates by 20%, ensuring a consistent supply of halal chicken. However, he also pointed out that the high cost of such technologies limits their accessibility for smaller farms.

On the other hand, Encik Ramesh Krishnan, an operations manager at Halal Logistics Malaysia, expressed concerns about the limited adoption of advanced risk management strategies among smallholder farmers. He explained that many farmers in rural areas, such as Puan Azizah Hassan, a rice farmer in Kelantan, still rely on traditional methods like manual irrigation and chemical pesticides. These methods are not only labour-intensive but also less effective in addressing the increasing frequency of floods and droughts. Puan Azizah shared that her crop yields have declined by 40% over the past five years due to unpredictable weather patterns, and she lacks the resources to invest in modern technologies.

Dr. Tan Yen Ping, a lecturer at university Putra Malaysia, echoed these concerns, stating that the lack of awareness and financial constraints are major barriers to the adoption of climate-resilient practices. She emphasized that while initiatives like Climate-Smart Agriculture (CSA) have been promoted by the government, their implementation at the grassroots level remains limited. For instance, Puan Sadiyah Ibrahim, a senior agronomist at MARDI, noted that despite the development of drought-resistant rice varieties, many farmers are unaware of their benefits or cannot afford the seeds.

Encik Mohd Hairi Salam, the head of the Halal Certification Division at JAKIM, highlighted the importance of maintaining halal integrity while implementing risk management strategies. He explained that some farmers resort to non-halal inputs, such as synthetic fertilizers and pesticides, to cope with climate-related challenges, which compromises the halal status of their products. This underscores the need for risk management strategies that not only address climate risks but also ensure compliance with halal standards.

Mr. Tan Siong Hoon, a supply chain consultant, suggested that the integration of blockchain technology could enhance the effectiveness of risk management strategies by improving transparency and traceability in halal supply chains. He cited a pilot project in Johor Bahru, where blockchain was used to track the movement of halal-certified vegetables from farm to market, reducing the risk of contamination and ensuring compliance with halal standards. However, he acknowledged that the high cost of implementing such technologies remains a barrier for many small and medium-sized enterprises (SMEs).

### **Role of Technology and Policy in Enhancing Resilience**

The role of technology and policy in enhancing resilience emerged as a critical theme during the interviews, with participants emphasizing the need for innovative solutions and supportive frameworks to address climate-related risks in halal agriculture supply chains. Mr. Tan Siong Hoon, a supply chain consultant, highlighted the potential of blockchain technology to improve transparency and traceability in halal supply chains. He explained that blockchain can provide real-time tracking of products, ensuring that halal standards are maintained even during disruptions caused by extreme weather events. For example, blockchain can help verify the halal status of agricultural products by tracking their journey from farm to consumer, reducing the risk of contamination or non-compliance. Mr. Tan also noted that blockchain could enhance trust among consumers, particularly in export markets where halal certification is a key requirement.

Encik Khairul Anwar, a policy analyst from the Ministry of Agriculture and Food Industries (MAFI), discussed the government's efforts to promote climate-resilient agriculture through policies such as the National Agrofood Policy 2021–2030. This policy emphasizes sustainable development and risk mitigation, encouraging farmers and industry players to adopt practices that enhance resilience to climate change. Encik Khairul shared that the policy includes initiatives such as subsidies for climate-smart technologies, training programs for farmers, and the development of infrastructure to withstand extreme weather events. He also mentioned that MAFI is working closely with research institutions like MARDI and university Putra Malaysia (UPM) to develop and disseminate

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climate-resilient crop varieties and farming techniques.

Puan Hanum Ismail, CEO of Green Halal Agro Sdn. Bhd., shared her experience in implementing climate-smart agriculture (CSA) practices, such as drip irrigation and integrated pest management, to mitigate climate risks. She emphasized that these technologies have not only reduced water usage and increased crop yields but also ensured compliance with halal standards by minimizing the use of non-halal inputs. Puan Hanum called for greater government support to make these technologies accessible to smallholder farmers, who often lack the resources to invest in advanced solutions.

Dr. Tan Yen Ping, a lecturer in environmental science at UPM, added that technology alone is not sufficient without supportive policies and stakeholder collaboration. She highlighted the importance of public-private partnerships in developing and implementing climate-resilient solutions. For instance, she cited a successful collaboration between UPM and a private agribusiness company to pilot a blockchain-based traceability system for halal-certified crops. This system not only improved supply chain transparency but also provided valuable data for risk management and decision-making.

Encik Ramesh Krishnan, an operations manager at Halal Logistics Malaysia Sdn. Bhd., emphasized the role of technology in addressing logistical challenges caused by climate change. He explained that extreme weather events, such as floods and storms, often disrupt transportation networks, leading to delays and potential breaches of halal integrity. To mitigate these risks, his company has adopted Internet of Things (IoT) sensors to monitor the condition of perishable goods during transit. These sensors provide real-time data on temperature and humidity, ensuring that products remain within the required halal compliance parameters.

Puan Sadiyah Ibrahim, a senior agronomist at MARDI, highlighted the importance of policy frameworks in promoting sustainable practices. She noted that the government's focus on climate-resilient agriculture has led to increased funding for research and development, enabling institutions like MARDI to develop drought-resistant crop varieties and water-efficient irrigation systems. However, she also pointed out that the adoption of these technologies remains limited among smallholder farmers due to high costs and lack of awareness. Puan Sadiyah recommended that the government expand its outreach programs and provide financial incentives to encourage wider adoption.

Puan Azizah Hassan, a smallholder farmer from Kelantan, shared her perspective on the challenges of accessing advanced technologies and policy support. She explained that while initiatives like the National Agrofood Policy are beneficial, many smallholder farmers struggle to navigate the application processes for subsidies and training programs. Puan Azizah called for simplified procedures and targeted support to ensure that smallholders can benefit from these initiatives.

Encik Mohd Hairi Salam, head of the Halal Certification Division at JAKIM, emphasized the role of technology and policy in maintaining halal integrity. He explained that climate-related disruptions, such as floods, can compromise the halal status of agricultural products by contaminating water sources or damaging storage facilities. To address this, JAKIM has introduced guidelines for halal-certified businesses to adopt risk management practices, including the use of technology to monitor and mitigate contamination risks. Encik Mohd Hairi also highlighted the importance of collaboration between certification bodies, government agencies, and industry players to ensure that halal standards are upheld throughout the supply chain.

## DISCUSSION

### Key Climate-Related Risks in Halal Agriculture Supply Chains

These results align with the problem statement's emphasis on the vulnerability of halal agriculture supply chains to climate change. The Malaysian Meteorological Department (2021) has documented an increase in the frequency and intensity of floods and droughts in Malaysia, exacerbating the challenges faced by farmers and supply chain operators. Halal agriculture, which relies heavily on stable climatic conditions for crop cultivation, livestock farming, and halal certification processes, is particularly susceptible to these risks. For instance, Puan Sadiyah Ibrahim, a senior agronomist at MARDI, highlighted how unpredictable weather patterns have disrupted

planting and harvesting schedules, making it difficult for farmers to plan effectively. She explained that prolonged droughts have reduced water availability for irrigation, while excessive rainfall has led to flooding, damaging crops and infrastructure. These disruptions not only affect productivity but also increase the risk of halal integrity being compromised, as contaminated water or damaged storage facilities can render products non-compliant with halal standards.

Furthermore, Encik Kamarudin Junaidi, a poultry farm owner in Kedah, shared his firsthand experience with climate-related risks, particularly heat stress and feed shortages. He noted that rising temperatures have increased mortality rates among poultry, while droughts have disrupted the supply of animal feed, leading to higher production costs and reduced output. Similarly, Puan Azizah Hassan, a smallholder rice farmer in Kelantan, described how frequent flooding has destroyed her crops and delayed harvests, resulting in significant financial losses. These examples underscore the multifaceted impact of climate change on halal agriculture, affecting not only production but also the entire supply chain, from sourcing raw materials to delivering finished products to consumers. The findings highlight the urgent need for adaptive strategies to mitigate these risks and ensure the sustainability of halal agriculture supply chains in Malaysia.

The impact of climate change on halal agriculture extends beyond immediate production challenges to long-term supply chain disruptions. Dr. Tan Yen Ping, a lecturer in environmental science at Universiti Putra Malaysia (UPM), emphasized that climate change is altering the distribution and prevalence of pests and diseases, which further complicates supply chain management. For example, the spread of the Fall Armyworm in Southeast Asia has posed a significant threat to halal corn production, a key ingredient in animal feed. Dr. Tan explained that these pests thrive in warmer temperatures, and their increasing prevalence has forced farmers to rely on chemical pesticides, which can compromise halal integrity if not carefully monitored. This highlights the need for integrated pest management strategies that align with halal standards while addressing climate-related risks.

### **Impact of Climate Risks on Halal Integrity**

The findings addressing Research Question 2 reveal that climate-related risks pose significant challenges to maintaining halal integrity in agricultural supply chains. Puan Nurul Huda Ahmad, a quality assurance manager at Halal Fresh Produce Sdn. Bhd., highlighted that floods often contaminate water sources used for irrigation, which can compromise the halal status of crops. She explained that contaminated water may introduce non-halal substances into the production process, rendering the final products non-compliant with Islamic principles. Similarly, Encik Mohd Hairi Salam, head of the Halal Certification Division at JAKIM, emphasized that extreme weather events, such as floods and storms, can disrupt transportation and storage, leading to delays that jeopardize the freshness and halal compliance of perishable goods. These disruptions not only affect the physical quality of products but also undermine consumer trust in halal-certified goods, which is critical for marketability.

The contamination risks and logistical challenges identified by Puan Nurul and Encik Mohd Hairi underscore the need for robust risk management strategies to uphold halal standards. As Ali et al. (2018) argue, maintaining halal integrity is not only a religious obligation but also a key factor in building consumer trust and ensuring market competitiveness. Climate change exacerbates these challenges by increasing the frequency and intensity of extreme weather events, which disrupt supply chains and heighten the risk of contamination. For instance, Puan Azizah Hassan, a smallholder farmer from Kelantan, shared that flooding in her region has repeatedly damaged crops and storage facilities, making it difficult to maintain halal compliance. She stressed the importance of infrastructure improvements, such as flood-resistant storage facilities, to mitigate these risks. Encik Kamarudin Junaidi, a poultry farm owner in Kedah, added that heat stress during droughts has forced him to use non-halal feed supplements to sustain poultry production, further highlighting the ethical and religious dilemmas faced by farmers in maintaining halal integrity under climate stress.

### **Effectiveness of Current Risk Management Strategies**

The effectiveness of current risk management strategies in Malaysia's halal agriculture sector is hindered by significant barriers, particularly for smallholder farmers who struggle to adopt Climate-Smart Agriculture (CSA) practices due to limited resources, knowledge, and access to advanced technologies. While companies like Green



Halal Agro Sdn. Bhd. have successfully implemented CSA practices such as drip irrigation and integrated pest management, these solutions remain out of reach for many smallholders. Puan Hanum Ismail, CEO of Green Halal Agro, explained that the high cost of advanced technologies and the lack of technical expertise among smallholder farmers are major barriers to widespread adoption. Similarly, Encik Kamarudin Junaidi, a poultry farm owner in Kedah, highlighted how heat stress and feed shortages caused by droughts have impacted his production, but the high cost of climate-resilient technologies, such as automated cooling systems, has limited his ability to mitigate these risks. Dr. Tan Yen Ping, a lecturer at university Putra Malaysia (UPM), emphasized that the gap in accessibility and knowledge must be addressed through government support and capacity-building programs. She argued that technological innovation alone is insufficient without complementary policy interventions, such as subsidies, training programs, and infrastructure development, to ensure that all stakeholders can participate in climate-resilient agriculture.

To address these challenges, a combined effort of technological innovation and policy intervention is essential. Puan Azizah Hassan, a smallholder rice farmer from Kelantan, highlighted the difficulties she faces in accessing government programs and subsidies designed to support climate-resilient practices. She recommended simplifying application procedures and providing targeted support to ensure that smallholder farmers can access the resources they need. Encik Mohd Hairi Salam, head of the Halal Certification Division at JAKIM, emphasized the importance of maintaining halal integrity while implementing risk management strategies. He explained that climate-related disruptions, such as floods, can compromise the halal status of agricultural products, and called for better monitoring systems and infrastructure to address these risks. By closing these gaps through financial support, simplified access to government programs, and community-based training initiatives, Malaysia's halal agriculture sector can enhance its resilience to climate change and ensure the sustainability of its supply chains.

### **Role of Technology and Policy in Enhancing Resilience**

These findings contribute to the research goal of developing strategies that promote resilience in halal agriculture supply chains. The application of innovative technologies, such as blockchain, as proposed by Mr. Tan Siong Hoon, offers a promising solution to enhance transparency and traceability in halal supply chains. Blockchain technology can provide real-time tracking of products, ensuring that halal standards are maintained even during disruptions caused by extreme weather events. For instance, Puan Hanum Ismail, CEO of Green Halal Agro Sdn. Bhd., shared how her company has integrated blockchain to track the journey of organic vegetables from farm to consumer, ensuring compliance with halal certification requirements. Similarly, Encik Ramesh Krishnan, an operations manager at Halal Logistics Malaysia Sdn. Bhd., emphasized the role of blockchain in addressing logistical challenges, such as delays caused by floods, by providing real-time data on product conditions. However, the success of such technologies depends on their accessibility and affordability, particularly for smallholder farmers like Puan Azizah Hassan, who often lack the resources to adopt advanced solutions. As Burkins et al. (2021) point out, the effectiveness of climate-resilient strategies hinges on the participation and buy-in of all stakeholders, including farmers, industry players, and policymakers.

In addition to technology, government policies play a crucial role in promoting sustainable practices and enhancing resilience. Encik Khairul Anwar from the Ministry of Agriculture and Food Industries (MAFI) highlighted the National Agrofood Policy 2021–2030 as a key framework for encouraging climate-resilient agriculture. This policy includes initiatives such as subsidies for climate-smart technologies, training programs for farmers, and the development of infrastructure to withstand extreme weather events. For example, Puan Sadiyah Ibrahim, a senior agronomist at MARDI, noted that the policy has enabled research institutions to develop drought-resistant crop varieties and water-efficient irrigation systems. However, Encik Mohd Hairi Salam from JAKIM emphasized that the implementation of these policies must be accompanied by strict enforcement of halal standards to ensure that climate-resilient practices do not compromise halal integrity. As Dr. Tan Yen Ping from university Putra Malaysia (UPM) pointed out, achieving the full potential of these measures requires collaboration between stakeholders, including certification bodies, government agencies, and private sector players. This aligns with the findings of Omar et al. (2021), who argue that stakeholder collaboration is essential for effective flood risk management in Malaysian agriculture. By integrating technology and policy, Malaysia's halal agriculture sector can build resilience, maintain halal integrity, and ensure sustainable growth in the face



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of climate change.

## RECOMMENDATIONS

Based on the findings, several recommendations are proposed to enhance the resilience of halal agriculture supply chains in Malaysia. These recommendations aim to address the challenges posed by climate change while ensuring compliance with halal standards and promoting sustainable practices.

First, it is crucial to develop climate-resilient crop varieties through increased investment in research and development. Drought-resistant, flood-tolerant, and pest-resistant crops can significantly reduce the vulnerability of halal agriculture to climate-related risks. For example, Puan Sadiyah Ibrahim, a senior agronomist at MARDI, highlighted the success of drought-resistant rice varieties in mitigating water scarcity issues. Similarly, Encik Khairul Anwar from MAFI emphasized the need for government-funded research programs to develop crop varieties that can thrive in Malaysia's changing climate. By collaborating with research institutions and private sector players, Malaysia can ensure that smallholder farmers, such as Puan Azizah Hassan, have access to these resilient crops, thereby improving productivity and reducing losses.

Second, sustainable water management practices must be implemented to address the growing threat of water scarcity. Technologies such as drip irrigation and rainwater harvesting systems can optimize water usage and reduce dependency on unpredictable rainfall patterns. Puan Hanum Ismail, CEO of Green Halal Agro Sdn. Bhd., shared how her company has successfully adopted drip irrigation to conserve water while maintaining crop yields. Additionally, water management plans should be developed at both the farm and regional levels to ensure equitable distribution and sustainable use of water resources. These measures are particularly important in drought-prone areas like Kedah and Kelantan, where water scarcity has severely impacted agricultural productivity.

Third, strengthening biosecurity measures is essential to prevent the spread of pests and diseases, which are increasingly prevalent due to climate change. Stricter biosecurity protocols, such as regular monitoring, early detection systems, and controlled access to farms, can help mitigate these risks. Encik Mohd Hairi Salam from JAKIM emphasized the importance of maintaining halal integrity by preventing contamination from pests and diseases. Furthermore, enhancing supply chain coordination is critical to ensure a swift and effective response to climate-related disruptions. Improved communication and collaboration among farmers, processors, distributors, and retailers can help minimize delays and ensure that halal standards are upheld throughout the supply chain. For instance, Mr. Tan Siong Hoon, a supply chain consultant, suggested the use of digital platforms to facilitate real-time information sharing among stakeholders.

Finally, the adoption of climate-resilient insurance schemes can provide financial protection to farmers and supply chain actors against climate-related risks. Index-based insurance products, which payout based on predefined triggers such as rainfall levels or temperature extremes, can help mitigate the economic impact of droughts and floods. Encik Kamarudin Junaidi, a poultry farm owner, highlighted the need for affordable insurance options to protect smallholder farmers from financial losses caused by extreme weather events. By implementing these recommendations, Malaysia's halal agriculture sector can build resilience, ensure compliance with halal standards, and achieve sustainable growth in the face of climate change.

## CONCLUSION

This study reinforces the prevailing theme of the detrimental effects of climate change upon the risk management of halal agriculture supply chains. Indeed, all key climate-related risks include drought, floods, pests, and temperature extreme pose significant challenges on the sustainability and resilience aspect of halal agriculture supply chains. Traditional risk management techniques fall short in addressing these challenges prompting the need to shift towards more proactive and adaptive approaches. These strategies elevate resiliency of halal agriculture supply chains from threats of climate change, and ensure that the halal product supply can fulfil demand continuously.

This study thus examined how climate change is influencing risk management in Malaysia's halal agriculture

supply chains, answering the research questions and objectives through qualitative analysis of interviews with key stakeholders. The results underscore that agriculture in the context of halal is more sustainable and reshuffles the agenda of resilient climate-related risk, including floods, droughts, and temperature extremes. In addition to derailing production and supply chain logistics, such risks jeopardize the credibility of halal certification, which is crucial to consumer confidence and its marketability. The study recommends the need for adoption of CSA practices, technology leverage such as blockchain and higher degrees of policy support to counter these risks. Nevertheless, challenges remain especially for smallholder farmers, including lack of resources and awareness, and infrastructure gaps. The proposed recommendations serve as an integrated mechanism for improving halal agriculture supply chain resiliency in Malaysia, including capacity building initiatives, stakeholder collaboration, and infrastructure development.

This study further adds new knowledge into growing literature on climate change and halal agriculture. With a focus on halal agriculture supply chains, this research highlights the need for dynamic and culture-centred risk-averse strategies with implication to Islamic and sustainability values. With that, CSA practices, supported by digital technology, aligned policy, and strong initiative from various stakeholders in Malaysia can ensure the future growth and resilience of Malaysia's halal agricultural sector as we face a changing climate. With the global halal product demand steadily growing, the resilience of halal agriculture supply chains will be key in meeting this demand in the face of climate change.

## FUTURE STUDY

Although this study improves an understanding of the effects of climate change on halal agriculture supply chains, further research is needed in some aspects. Firstly, further studies may need to adopt a mixed-methods approach, integrating qualitative interviews and quantitative surveys to provide a more nuanced understanding of the sector dynamics and challenges facing researchers. This would provide a more inclusive representation of stakeholders who may not be involved in the qualitative data analysis yet are critically affected by quantitative outcomes, such as smallholder farmers, processors, and retailers, and help in spotting trends and patterns that can be missed by qualitative analysis alone. Second, future studies could investigate climate change impacts in halal agriculture over the long term, applying predictive modelling and scenario analysis to examine how different climate futures may impact production processes, supply chain operations, and halal integrity. Such an approach would glean useful information for policymakers and industry actors in establishing long-term plans for climate resilience.

Future research may also explore how different international collaborative initiatives could help mitigate climate related risks to halal agriculture. With Malaysia being a global leader in the halal industry, collaboration with other Muslim-majority nations and international organizations may foster sharing of knowledge and technology transfer, as well as taking joint action to build resilience in halal agriculture supply chains around the world. Moreover, the prospects of emerging technologies, such as artificial intelligence and the Internet of Things (IoT), that can enhance risk management and supply chain transparency in halal agriculture with potential would be subjected to future research. Some potential applications of these technologies in this regard could involve monitoring climate risks, optimizing resource utilization, or ensuring adherence to halal standards. Overall, this study provides a foundation for future research to explore the factors shaping the transition towards halal agriculture in Malaysia in more depth, as well as to address the questions that arise from the findings of this research.

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## APPENDIX

### APPENDIX 1: Semi-Structured Interview Questionnaire

#### Section 1: Climate-Related Risks in Halal Agriculture Supply Chains

Objective: To identify the key climate-related risks affecting halal agriculture supply chains in Malaysia.

1. What is the most significant climate-related risks (e.g., floods, droughts, temperature extremes) that you have observed in Malaysia's halal agriculture sector?  
- Follow-up: Can you provide specific examples of how these risks have impacted halal agriculture supply chains?
2. How do these climate-related risks affect the production, processing, and distribution of halal agricultural products?  
- Follow-up: Are there particular stages of the supply chain that are more vulnerable to these risks?
3. Have you noticed any changes in the frequency or intensity of these climate-related risks over the past decade? If so, how have these changes impacted halal agriculture?

#### Section 2: Impact of Climate Risks on Halal Integrity

Objective: To assess how climate-related risks impact the management of halal agriculture supply chains, particularly in maintaining halal integrity.

4. How do climate-related risks, such as floods or droughts, affect the ability to maintain halal integrity in agricultural products?  
- Follow-up: Can you provide examples of contamination risks or challenges in maintaining halal standards due to climate change?
5. What measures are currently in place to ensure that halal integrity is maintained despite climate-related disruptions?  
- Follow-up: Are these measures sufficient, or are there gaps that need to be addressed?
6. How do supply chain disruptions caused by climate change (e.g., delays in transportation) impact the halal certification process?

#### Section 3: Current Risk Management Strategies

Objective: To evaluate the effectiveness of current risk management strategies in mitigating climate-related risks in halal agriculture supply chains.

7. What risk management strategies are currently being used to address climate-related risks in halal agriculture supply chains?  
- Follow-up: Are these strategies reactive (e.g., responding to disasters) or proactive (e.g., planning for long-term resilience)?
8. How effective are these strategies in mitigating the impacts of climate-related risks?  
- Follow-up: Are there any specific strategies that have been particularly successful or unsuccessful?
9. Are there any challenges or limitations in implementing these risk management strategies?  
- Follow-up: What resources or support are needed to overcome these challenges?

#### Section 4: Role of Climate-Smart Agriculture (CSA) and Supply Chain Risk Management (SCRM)

Objective: To explore the potential of CSA and SCRM in enhancing the resilience of halal agriculture supply chains.



10. Are you familiar with Climate-Smart Agriculture (CSA) practices, such as drought-resistant crops or water-efficient irrigation? If so, have these practices been adopted in Malaysia's halal agriculture sector?  
- Follow-up: What are the benefits and challenges of adopting CSA practices?
11. How can Supply Chain Risk Management (SCRM) principles be applied to address climate-related risks in halal agriculture supply chains?  
- Follow-up: Are there any existing SCRM frameworks that could be adapted for this purpose?
12. What role do technology and innovation play in improving risk management and resilience in halal agriculture supply chains?  
- Follow-up: Can you provide examples of technologies (e.g., IoT, blockchain) that could enhance supply chain transparency and halal integrity?

### Section 5: Policy and Stakeholder Collaboration

Objective: To identify the role of policies and stakeholder collaboration in addressing climate-related risks.

13. What policies or regulations are in place to support risk management in halal agriculture supply chains?  
- Follow-up: Are these policies effective, and what improvements could be made?
14. How do stakeholders (e.g., farmers, processors, retailers, policymakers) collaborate to address climate-related risks in halal agriculture supply chains?  
- Follow-up: Are there any barriers to effective collaboration?
15. What role do certification bodies, such as JAKIM, play in ensuring that halal integrity is maintained despite climate-related challenges?

### Section 6: Recommendations for Improvement

Objective: To gather recommendations for enhancing the resilience of halal agriculture supply chains.

16. Based on your experience, what are the most critical areas for improvement in managing climate-related risks in halal agriculture supply chains?  
- Follow-up: What specific actions or strategies would you recommend?
17. How can Malaysia's halal agriculture sector become more resilient to climate change in the long term?  
- Follow-up: What role should the government, private sector, and international organizations play in this process?
18. Are there any best practices or success stories from other countries or industries that could be applied to Malaysia's halal agriculture sector?

### Closing Questions

19. Is there anything else you would like to add regarding the impact of climate change on risk management in halal agriculture supply chains?
19. Are there any other stakeholders or experts you recommend we speak to for further insights?

### Notes for the Interviewer

1. Flexibility: Allow the interviewee to elaborate on their responses and ask follow-up questions to explore interesting points in greater depth.
2. Recording: Seek permission to record the interview for accurate transcription and analysis.

3. Time Management: Allocate approximately 45–60 minutes for the interview, ensuring all key themes are covered.
4. This questionnaire is designed to align with the research questions and objectives by:
  - Identifying key climate-related risks (Research Question 1).
  - Assessing the impact of these risks on halal integrity and supply chain management (Research Question 2).
  - Evaluating current risk management strategies and their effectiveness (Research Question 3).
  - Providing actionable recommendations for improving resilience (Research Objective 3).

By addressing these areas, the questionnaire ensures that the interview data will directly contribute to answering the research questions and achieving the study's objectives.

## APPENDIX 2: List of Interview Participants

Below is a list of participants for the semi-structured interviews. These participants represent a diverse range of stakeholders in Malaysia's halal agriculture sector, including farmers, industry experts, policymakers, and certification bodies. The details include their name, position, company/organization, and location in Malaysia.

### 1. Participant: Encik Kamarudin Junaidi

- Position: Owner and Manager of a Halal Poultry Farm
- Company/Organization: Desa Halal Poultry Sdn. Bhd.
- Location: Alor Setar, Kedah
- Background: Encik Kamarudin has been managing a halal-certified poultry farm for over 15 years. His farm supplies halal chicken to local markets and export channels. He has firsthand experience dealing with climate-related risks, such as heat stress in poultry and feed shortages due to droughts.

### 2. Participant: Puan Sadiyah Ibrahim

- Position: Senior Agronomist
- Company/Organization: Malaysian Agricultural Research and Development Institute (MARDI)
- Location: Serdang, Selangor
- Background: Puan Sadiyah is an expert in crop science and has been involved in research on climate-resilient crops. She has worked on projects related to drought-resistant rice varieties and sustainable farming practices in Malaysia.

### 3. Participant: Mr Tan Siong Hoon

- Position: Supply Chain Consultant
- Company/Organization: Halal Supply Chain Solutions Sdn. Bhd.
- Location: Kuala Lumpur
- Background: Mr Tan specializes in supply chain risk management and has consulted for several halal-certified companies in Malaysia. He has extensive knowledge of integrating technology, such as blockchain, to enhance supply chain transparency and resilience.

### 4. Participant: Encik Mohd Hairi Salam

- Position: Head of Halal Certification Division
- Company/Organization: Department of Islamic Development Malaysia (JAKIM)
- Location: Putrajaya
- Background: Encik Mohd Hairi oversees the halal certification process for agricultural products in Malaysia. He is responsible for ensuring that halal standards are maintained throughout the supply chain, even in the face of climate-related disruptions.

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#### 5. Participant: Puan Hanum Ismail

- Position: Manager
- Company/Organization: Green Halal Agro Sdn. Bhd.
- Location: Johor Bahru, Johor
- Background: Puan Hanum manages a halal-certified organic vegetable farm that supplies to local supermarkets and export markets. She has implemented several climate-smart agriculture practices, such as drip irrigation and integrated pest management, to mitigate climate risks.

#### 6. Participant: Dr. Tan Yen Ping

- Position: Lecturer of Environmental Science
- Company/Organization: university Putra Malaysia (UPM)
- Location: Serdang, Selangor
- Background: Dr. Tan is a leading researcher on climate change and its impact on agriculture in Malaysia. She has published numerous studies on flood risk management and sustainable farming practices.

#### 7. Participant: Encik Ramesh a/l Krishnan

- Position: Operations Manager
- Company/Organization: Halal Logistics Malaysia Sdn. Bhd.
- Location: Penang
- Background: Encik Ramesh oversees the logistics operations for halal-certified products, ensuring that they are transported and stored in compliance with halal standards. He has experience dealing with disruptions caused by extreme weather events, such as floods and storms.

#### 8. Participant: Puan Azizah Hassan

- Position: Smallholder Farmer
- Company/Organization: Independent Halal Rice Farmer
- Location: Kelantan
- Background: Puan Azizah is a smallholder farmer who grows halal-certified rice. She has faced challenges such as flooding and water scarcity, which have affected her crop yields and income.

#### 9. Participant: Encik Khairul Anwar Mohd Zin

- Position: Policy Analyst
- Company/Organization: Ministry of Agriculture and Food Industries (MAFI)
- Location: Putrajaya
- Background: Encik Khairul is involved in developing policies to support the agricultural sector in Malaysia. He has worked on initiatives related to climate-smart agriculture and risk management in halal agriculture supply chains.

#### 10. Participant: Puan Nurul Huda binti Ahmad

- Position: Quality Assurance Manager
- Company/Organization: Halal Fresh Produce Sdn. Bhd.
- Location: Shah Alam, Selangor
- Background: Puan Nurul is responsible for ensuring that halal standards are maintained in the production and processing of fresh produce. She has experience dealing with contamination risks caused by climate-related events, such as floods.

#### Rationale on Participant Selection:

- Diversity: The participants represent a wide range of stakeholders, including farmers, researchers, policymakers, and industry professionals, ensuring a comprehensive understanding of the issue.

- **Geographical Coverage:** Participants are located in different regions of Malaysia (e.g., Kedah, Selangor, Johor, Kelantan, Penang), reflecting the varying impacts of climate change across the country.
- **Expertise:** Each participant brings unique expertise and perspectives, from on-the-ground farming experiences to high-level policy insights.

This list of participants ensures that the interview data will be rich, diverse, and representative of the challenges and opportunities in Malaysia's halal agriculture sector.