

Sugarcane Burning: Why?

Sudarin Rodmanee¹, Aeumporn Loypradit² & Chiraphorn Parnporm¹

¹ Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Bangkok, Thailand

² Faculty of Holistic Learning Academy in Social Entrepreneurship, Arsom Silp Institute of the Arts, Bangkok, Thailand

Correspondence: Sudarin Rodmanee, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Paholayothin Road, Chatuchak District, 10900, Bangkok, Thailand. E-mail: sudarin@hotmail.com

Received: February 21, 2024

Accepted: April 30, 2024

Online Published: June 5, 2024

doi:10.5539/ibr.v17n4p1

URL: <https://doi.org/10.5539/ibr.v17n4p1>

Abstract

The sugarcane harvesting practices of farmers pose a recurring problem of burning the sugarcane fields every year, leading to the release of PM 2.5, which is hazardous to health and a matter of concern for all parties involved. The objective of this research is to investigate the causes of sugarcane burning by farmers. Data is collected through participatory observation methods and group discussions with a sample group of farmers in the provinces with the highest incidents of sugarcane field fires, namely Nakhon Ratchasima, Kalasin, and Khon Kaen in the northeastern region of Thailand during the 2021/2022 production season. Content analysis techniques are employed to identify the reasons behind the behavior of burning sugarcane. The findings reveal that sugarcane burning has been a long-standing practice among farmers, and the prevalence of burning has increased due to a shortage of labor for sugarcane cutting. The available machinery for sugarcane cutting is insufficient and unsuitable for the farmers' fields. Farmers who burn sugarcane fields are aware of the health impacts and have benefited from the government's measures to address the issue of sugarcane field fires. However, it is observed that the quantity of burnt sugarcane still exceeds the government's target, because burning sugarcane is a cost-effective, convenient, and rapid method. It is found that penalizing farmers at a rate of 30 Baht per ton of burnt sugarcane and providing assistance at a rate of 120 Baht per ton of fresh-cut sugarcane does not sufficiently motivate farmers to change their sugarcane burning behavior.

Keywords: Fire Sugarcane, Burn Sugarcane, PM 2.5, Sugarcane Farmer

1. Introduction

Sugarcane is an economic crop in Thailand used as a raw material for sugar production and ranks as the second-largest exporter globally, after Brazil. The sugarcane harvesting season begins in November and lasts until May every year. Most farmers choose the method of burning sugarcane before harvesting, commonly known as "slash-and-burn." The burning of sugarcane and agricultural residues contributes to air pollution, similar to vehicle emissions, increasing the levels of fine particulate matter, known as PM 2.5, which poses significant health risks to the general population. This issue becomes more severe during the dry season when there is a lack of rainfall (Department of Pollution Control, 2020).

The government has identified PM 2.5 pollution as a national priority that requires urgent attention. Several measures have been approved to address the issue of sugarcane burning, including:

- 1) Setting quotas for sugarcane entering mills: For the 2023/2024 production season, the target is to limit the amount of burnt sugarcane entering mills to no more than 10% of the total harvest. In the 2024/2025 season, the limit will be reduced to 5%, and for the 2025/2026 season, it will be 0%.
- 2) Imposing fines on sugarcane farmers who burn their crops: A fine of 30 Baht per ton of burnt sugarcane will be deducted from their earnings.
- 3) Imposing penalties on factories that accept burnt sugarcane beyond the set limits.
- 4) Providing mechanical sugarcane harvesters to farmers for easier harvesting and preparing the land after the harvest.
- 5) Promoting the purchase of green sugarcane leaves to increase farmers' income and reduce post-harvest burning.

- 6) Seeking cooperation from sugar mills to ensure a fair purchase price for freshly cut sugarcane during at least two production seasons. Additionally, mills should prioritize the immediate reception of freshly cut sugarcane.
- 7) Providing financial assistance from the government to reduce the cost of harvesting sugarcane for farmers during at least two production seasons.
- 8) Supporting low-interest loans for sugarcane farmers to purchase agricultural machinery, such as cane cutters and other equipment, for use in their fields (Office of Cane and Sugar Board, 2022).

However, the Ministry of Industry reported that in the 2024/2025 production season, the quantity of sugarcane delivered to sugar mills was 92.07 million tons. Out of this, 66.95 million tons were fresh sugarcane, accounting for 72.72%, while burnt sugarcane amounted to 25.12 million tons, accounting for 27.28%. These figures did not meet the target, which aimed to limit the burnt sugarcane to no more than 10% of the total harvest. The increase in burnt sugarcane was primarily due to continuous rainfall, which caused a significant amount of sugarcane to fall, hindering the harvesting process. Furthermore, it was found that the quantity of burnt sugarcane in the 2024/2025 season increased by 7.51% compared to the previous season. In the 2023/2024 season, the quantity of sugarcane delivered to sugar mills was 66.66 million tons, with 49.05 million tons being fresh sugarcane (52.77%) and 17.61 million tons burnt sugarcane (18.95%) (Office of Cane and Sugar Board, 2022).

Based on the aforementioned information, it can be concluded that air pollution may not be the sole factor contributing to the increased burning of sugarcane. It is essential to gain a comprehensive understanding of the situation from all perspectives.

2. Literature Review

2.1 Sugarcane Cultivation

Sugarcane is a monocot plant classified under the family Gramineae. It thrives well in hot climates and is an easily cultivated crop. However, achieving high yields and good quality sugarcane depends on various factors, including favorable growing conditions. These factors include well-drained soil that does not get flooded throughout the year and deep soil with a minimum depth of 80 centimeters. As sugarcane is a perennial plant, it has a fibrous root system that spreads around the stem and requires fertile soil for optimal productivity and high weight. Additionally, sugarcane plantations should be in areas with convenient transportation and proximity to sugar factories to reduce costs and facilitate transportation. In Thailand, sugarcane is grown in various regions, including the northern, central, northeastern, and eastern regions, with the highest cultivation in the northeastern region. Presently, farmers prefer to cultivate the Khon Kaen 3 sugarcane variety (Meepunya & Chanthakul, 2014; Kamlha, 2020; Sakul-Ariyarnit, Thawornphreuk, & Jitmat, 2021). The years 2017/2018 to 2021/2022, the harvested area, production, and yield per hectare of sugarcane have shown a decreasing trend of 5.59%, 12.79%, and 7.50% per year, respectively. In the 2017/2018 season, the harvested area was 11.19 million rai, with a production of 131.72 million tons and a yield of 11.68 tons per hectare. However, in the 2021/2022 season, the harvested area decreased to 9.53 million rai, with a production of 92.05 million tons and a yield of 9.66 tons per hectare. This decline can be attributed to factors such as the reduction in sugarcane factory prices, drought conditions, and the impact of the COVID-19 pandemic. These factors have discouraged sugarcane farmers from increasing cultivation, resulting in decreased harvested areas, production, and yield per hectare. Additionally, there has been a shortage of labor for sugarcane cutting and higher prices for harvesting machinery (Office of Agricultural Economics, 2022). During the 2021/2022 season, the total quantity of sugarcane delivered to sugar mills nationwide was 92.07 million tons, consisting of 66.95 million tons of fresh sugarcane and 25.12 million tons of burned sugarcane. In the northeastern region, which accounts for nearly half of the country's sugarcane cultivation, the quantity of sugarcane delivered to sugar mills was 46.18 million tons (30.06 million tons of fresh sugarcane and 16.12 million tons of burned sugarcane). The central region delivered 21.65 million tons (17.68 million tons of fresh sugarcane and 3.97 million tons of burned sugarcane), the northern region delivered 19.78 million tons (16.61 million tons of fresh sugarcane and 3.17 million tons of burned sugarcane), and the eastern region delivered 4.46 million tons (2.60 million tons of fresh sugarcane and 1.86 million tons of burned sugarcane) (Office of Cane and Sugar Management, 2022).

Fine particles, also known as PM 2.5, are solid or semi-volatile particles with an aerodynamic diameter smaller than 2.5 micrometers. This has become a significant issue in various areas, having long-term implications on public health. According to data from the Department of Pollution Control, the main causes of PM 2.5 problems are identified as follows: 1) the combustion of diesel engines and 2) the burning of crops in agricultural fields. The northeastern region of Thailand, which is predominantly used for sugarcane cultivation, experiences a high incidence of PM 2.5 issues from December to April during the sugarcane harvesting season. The severity of this problem increases during dry periods with minimal rainfall, as the limited precipitation fails to effectively

cleanse the fine particles. Consequently, the burning of sugarcane can be considered a contributing factor to this issue (Nualyai, 2019). Numerous research studies have demonstrated the adverse effects of PM 2.5 on visibility and human health in Thailand, primarily affecting the respiratory and nervous systems, leading to allergies, skin diseases, and lung cancer (Suchaoint, 2019). Furthermore, the Department of Pollution Control has set a standard for PM 2.5 concentration in the general atmosphere, limiting it to 50 µg/m³ for a 24-hour period (Mheunmee & Butrdee, 2021).

2.2 Related Researches

Wuttiphan Lhuengvilai (2015) found that sugarcane plantation owners in Nakhon Pathom province faced labor issues in the sugarcane harvesting area, with an aging workforce and younger workers increasingly moving into industrial and service sectors. This led to the need to hire labor from the northeastern region. It was also found that laborers did not always fulfill their contractual obligations, making it difficult for plantation owners to find labor. Consequently, they resorted to the practice of burning sugarcane leaves before harvesting to reduce labor-related issues and enable faster sugarcane cutting, ensuring timely delivery to factories. However, this method resulted in various environmental problems and also led to a deduction in the initial sugarcane price paid by sugar factories. As a solution, some plantation owners opted to rent sugarcane cutting machines from sugar factories as an alternative to labor, while others employed both laborers and machines simultaneously. These findings align with the research conducted by Supakorn Phoem and Santi Saenglertsawai (2016), who discovered that 66.70% of sugarcane farmers in Suphanburi province chose to burn sugarcane due to its convenience and speed in harvesting, as well as labor shortage issues. Additionally, 22.40% of farmers did not decide to burn sugarcane but had to cut it due to problems related to fire-setting incidents. It was also found that if laborers chose to cut burned sugarcane, their average income was higher compared to cutting fresh sugarcane, even though the wages for cutting fresh sugarcane were higher. However, this average income was still lower than what laborers earned from cutting fresh sugarcane. Only a small number of farmers chose to use cutting machines due to unfavorable terrain conditions, and the use of machines caused damages during the harvesting process. Moreover, a study on pre-harvest sugarcane burning in Suphanburi and Kanchanaburi provinces revealed a continuous increase in the quantity of burned sugarcane over time. The groups primarily affected by burned sugarcane were the laborers who cut the burned sugarcane and the households impacted. They were aware of the health implications and expressed moderate concern about this issue. Pre-harvest sugarcane burning in the sugarcane-growing areas of Suphanburi province caused an economic loss of up to 296 million baht per harvest season, while Kanchanaburi province suffered a loss of 192 million baht per season. The government needs to expedite measures to reduce sugarcane burning by farmers, such as potentially increasing the deduction rate for sugarcane burning from 30 baht per ton to 68 baht, which would be an appropriate rate. This should be a joint responsibility shared by both farmers and sugar factories. The funds collected could then be redistributed to farmers who sell freshly cut sugarcane, serving as an incentive for farmers to reduce pre-harvest sugarcane burning (Sinpermsuksakul, 2019).

3. Research Objectives

To investigate the behaviors and causes of pre-harvest and post-harvest sugarcane burning among sugarcane farmers.

4. Scope of Research

The study will be conducted in three provinces in the northeastern region of Thailand, which have the highest quantities of burned sugarcane in the top three ranks during the 2021/2022 production season. These provinces and their respective quantities are as follows:

- 1) Nakhon Ratchasima: 7.67 million tons (3.96 million tons of fresh sugarcane, 3.71 million tons of burned sugarcane)
- 2) Kalasin: 4.43 million tons (2.07 million tons of fresh sugarcane, 2.36 million tons of burned sugarcane)
- 3) Khon Kaen: 3.13 million tons (2.39 million tons of fresh sugarcane, 0.74 million tons of burned sugarcane)

5. Research Methodology

This research utilizes a qualitative research approach, collecting data from sugarcane farmers and factories during the 2021/2022 production season in the study area of three provinces, with the highest incidents of sugarcane field fires, in the northeastern region of Thailand.

Data collection involved conducting focus group discussions in May 2022. In focus group discussions, the researchers facilitated the discussions by posing questions, raising topics for conversation, probing participants' thoughts and feelings, using cue cards, and tree diagrams to stimulate discussion and gather information from the

sample group. Additionally, non-participatory observation was employed in this research.

The selection of target groups for each focus group discussion employed a purposive sampling technique. Initially, data on geographical information were studied to determine the region with the highest sugarcane deliveries in the country during the 2021/2022 production season, specifically the northeastern region. Then, the top three provinces with the highest quantities of burned sugarcane in the northeastern region were selected, namely Nakhon Ratchasima, Kalasin, and Khon Kaen. Subsequently, the sample group criteria were defined as follows:

- 1) Large-scale sugarcane farmers with over 100 rai of cultivation, totaling 2 participants.
- 2) General sugarcane farmers, totaling 6 participants.
- 3) Community leaders who are also sugarcane farmers, totaling 2 participants per province, amounting to a total of 40 participants.

The researchers coordinated with the sugarcane farmers' association in the area to assist in the selection and arrangement of meetings with farmers to gather their opinions on issues related to sugarcane burning, causes of burning, pre- and post-harvest management, and the impacts, advantages, and disadvantages of sugarcane burning. For data analysis, the researchers employed content analysis, using data from documents and information obtained from the focus group discussions to ensure the completeness of research objectives. The collected data were categorized, analyzed, and linked to identify relationships, supported by findings from the review of relevant geographical information data. Finally, conclusions were drawn.

6. Results and Discussion

6.1 Characteristics of Farmers

Farmers can be classified into two main types:

- 1) Large-scale farmers: These farmers have more than 100 rai of sugarcane cultivation. They are primarily quota leaders who own their own machinery and equipment. They collect and purchase sugarcane from small-scale farmers to supply it to sugar factories. These farmers harvest fresh sugarcane using sugarcane cutters without burning the crops before harvesting. After harvesting, they leave the sugarcane leaves in the field, with some burning the leaves in certain areas. Some farmers use sugarcane leaves as mulch and plow them into the soil as organic fertilizer. Others compact the sugarcane leaves into bales and sell them to biomass power plants.
- 2) Small-scale farmers: These farmers have less than 100 rai of sugarcane cultivation. They use small machinery and equipment for sugarcane planting and harvesting. Some of these farmers rely on household labor and hired labor for sugarcane cutting. Many of them prefer to burn the sugarcane before selling it to sugar factories. When selling sugarcane, they often burn the leaves. If they hire machinery to harvest fresh sugarcane, they may sell the leaves to entrepreneurs who compact them into bales for biomass power plants or leave the leaves to cover the fields to maintain soil moisture.

The characteristics of the farmers in different categories indicate variations in their farming practices, particularly in terms of burning sugarcane and the utilization of sugarcane leaves after harvesting.

6.2 Sugarcane Harvesting Practices of Farmers

There are three methods of harvesting:

- 1) Burning and manual cutting: Farmers burn the sugarcane leaves before harvesting to facilitate the process. This allows them to cut the sugarcane easily and quickly. Once cut, the sugarcane stalks are piled together, awaiting transportation.
- 2) Manual cutting of fresh sugarcane: Farmers use knives to cut the sugarcane stalks close to the ground, removing the leaves. After cutting, they bundle the sugarcane together, ready for transportation.
- 3) Cutting fresh sugarcane using machinery: This method involves cutting the sugarcane without burning the leaves before the cutting process. The sugarcane cutting machine uses blades to remove the top portion of the sugarcane and cuts the stalks at the base. The sugarcane stalks are then shredded into small sections and conveyed along a belt. The lightweight sugarcane leaves are blown away by the machine's air blower, while the heavier sections are sprayed into accompanying trucks for immediate transport to the sugar factory. New trucks are often used in conjunction with the sugarcane cutting machine.

The Office of Cane and Sugar Board (2022) reports that the wage for cutting fresh sugarcane is set at 200 baht per ton, with an average daily yield of 2.125 tons, resulting in a wage of 425 baht per day. On the other hand, the wage for cutting burnt sugarcane is 112.5 baht per ton, with an average yield of 6 tons, resulting in a wage of 675

baht per day. Contractors who cut fresh sugarcane receive a lower daily wage, around 250 baht, compared to those who cut burnt sugarcane. Therefore, the government provides additional assistance to farmers who cut fresh sugarcane, increasing their daily wage by 120 baht to match the wage of contractors who cut burnt sugarcane. This support aims to aid sugarcane farmers in the industrial sector who produce high-quality fresh sugarcane for delivery to all sugar factories. Using machinery for sugarcane harvesting is faster than manual labor, and farmers can hire sugarcane cutting machines, forage harvesters, and sugarcane transport trucks on a per-ton basis. The average hiring rate for sugarcane cutting machines is approximately 150-200 baht per ton, while the cost of truck transportation and forage harvesters is around 130-150 baht per ton. The hiring costs vary depending on the distance between the sugarcane fields and the sugar factory, as well as labor costs in the respective areas.



Figure 1. Burned Sugarcane Harvesting through Manual Labor

Source: The Isaan Record (2019)



Figure 2. Fresh Sugarcane Harvesting through Manual Labor

Source: Researcher (2022)



Figure 3. Sugarcane Harvesting through the use of Mechanical Harvesters

Source: T.K. Equipment Co., Ltd. (2022)

6.3 Sugarcane Stalk Harvest Management Practices

The method of harvesting sugarcane directly affects the management of sugarcane leaves. If farmers use the method of burning the sugarcane field and cutting the burnt sugarcane, there will be no leaves left in the field. However, if fresh sugarcane is harvested without burning, the quantity and characteristics of the leaves and tops of the sugarcane obtained will vary depending on the harvesting method. It has been observed that farmers employ three different post-harvest leaf management practices, which are as follows:

1) Leaf Burning: After harvesting fresh sugarcane by cutting, farmers leave the leaves exposed to the sun in the field for about 2-3 days. Once it is observed that the sugarcane leaves are thoroughly dry, a firebreak is established to prevent the fire from spreading beyond the designated area. Then, a fire is ignited to burn the leaves during the late evening or early morning hours when the wind is not strong, ensuring that the fire does not spread uncontrollably. The fire is gradually extinguished by manual inspection and the use of backpack sprayers to dampen the fire until it is completely out. In some areas, farmers wait for satellite measurements of heat radiation in the desired field before igniting the fire. Once the leaves and tops of the sugarcane have burned completely, the fire is slowly extinguished. Farmers who wish to burn the leaves must notify community leaders to schedule the burning. The number of individuals allowed to burn should not exceed three per day. Each individual must prepare their own firebreak to prevent the fire from spreading to other fields. Community leaders only permit burning during the late evening hours. For example, in certain areas, the fire is ignited and completely extinguished before midnight. Before igniting the fire, the individuals responsible for the burning must inspect the firebreak. If anyone violates the rules and burns leaves without notifying the community leaders, they will be apprehended and fined immediately. However, in reality, no such cases have been reported in that area. If the fire spreads to other fields that do not belong to the individual who ignited the fire, the owner of the field where the fire originated must compensate for the damages.

2) Mulching with Sugarcane Leaves: After completing the harvesting of fresh sugarcane, farmers use a tractor-mounted blade to collect and spread the leaves evenly throughout the field. This process aims to create a thick and uniform layer of sugarcane leaves covering the entire field. Additionally, farmers use Vinasse water from a nearby sugarcane factory to improve the soil and facilitate the decomposition of leaves and sugarcane tops in the field. Afterward, the soil is prepared for normal sugarcane cultivation. The combination of Vinasse water and chemical fertilizers in the field promotes the growth of sugarcane and yields better results compared to using only chemical fertilizers. Chemical fertilizers release nutrients to the sugarcane rapidly during the initial growth stage, while the organic materials gradually release nutrients to support long-term growth. (Ditkamol, T., 2008)

3) Compressing Sugarcane Leaves for Bioenergy Power Plants: After the completion of sugarcane harvesting, individual farmers sell their leaves to contractors responsible for compressing the leaves. In each area, there is a similar purchasing price range of approximately 50-200 baht per rai. The leaf compressing contractors then sell the leaves to designated collection points at a price range of 700-1,500 baht per ton to bioenergy power plants.



Figure 4. Sugarcane Leaf Burning Site after Harvesting
Source: Researcher (2022)



Figure 5. Utilization of Sugarcane Leaves for Soil Mulching using Vinasse in Sugarcane Fields prior to Plowing
Source: Mitrapol Modern Farm (2021) and Researcher (2022)



Figure 6. Sugarcane Leaf Compression for Sale to Biomass Power Plants
Source: Researcher (2022)

6.4 Causes and Conditions for Sugarcane Burning Before and After Harvesting

Through data collection and analysis, it was found that there are different causes and conditions for sugarcane burning before and after harvesting. The burning of sugarcane before harvesting involves managing the main source of income for farmers, which is the harvested sugarcane. On the other hand, burning sugarcane leaves after harvesting involves managing the remaining residues from cutting fresh sugarcane. The reasons and conditions for each are explained as follows:

6.4.1 Causes and Conditions for Sugarcane Burning Before Harvesting

1) Cost of sugarcane harvesting: In the 2021/2022 production season, the cost of sugarcane production increased

due to labor costs, interest on investment, and fuel costs. Burning sugarcane was found to have the lowest cost compared to cutting fresh sugarcane with manual labor or using machinery. This is consistent with the information provided by OCSB.

2) The unsuitable terrain, field conditions, and climate for using sugarcane harvesters are factors that prevent some farmers from using mechanical harvesters. Some farmers grow sugarcane in hilly areas, areas with rocks, sloping land, or areas prone to waterlogging. The sugarcane fields have irregular shapes, narrow spaces, and fewer rows. In some areas, the sugarcane crop gets knocked down due to rainstorms before harvest, making it impossible to use mechanical harvesters. This aligns with the research conducted by Supakorn Phoem and Santi Saenglersawai (2016), who found that a minority of sugarcane farmers in the Suphanburi province opt for mechanical harvesters due to the unfavorable conditions and the associated damage that occurs during harvesting.

3) Labor shortage, aging workforce, and the unavailability of foreign labor for sugarcane harvesting were significant challenges faced by farmers during the 2021/2022 production season. The COVID-19 pandemic has disrupted the influx of foreign labor, which was a primary source for sugarcane harvesting. The majority of laborers prefer to work on sugarcane burning activities due to the faster and easier nature of the task, as well as the higher daily wages compared to manual harvesting. This finding is consistent with the research conducted by Cherdchu Kong-on & Yot Borisut, (2013), which revealed that labor shortage and rising wages were factors contributing to farmers resorting to pre-harvest burning. Additionally, sugarcane farmers aim to harvest their crops quickly and in large quantities to facilitate prompt sales, generating income for hiring labor to harvest in other fields or purchasing additional sugarcane from small-scale farmers to fulfill their contractual obligations with the factories.

4) Number of sugarcane cutting machines: In some areas, there is an insufficient number of sugarcane cutting machines to meet the demands of farmers. As a result, farmers have to wait in long queues, which is not feasible as they need to harvest their crops promptly before the closure of the milling season.

5) Factory support and local preferences: Some sugar mills in certain areas do not offer price guarantees for purchasing fresh sugarcane, leading to a lack of motivation among farmers to cut high-quality fresh sugarcane. Additionally, some factories do not prioritize farmers who cut fresh sugarcane and do not provide them with preferential treatment. This is in contrast to areas where farmers are supported by factories to cut fresh sugarcane at higher prices compared to the initial sugarcane price, and they are given priority over those burning sugarcane. The long and dirty burning residues are considered contaminants that reduce the sugar yield per ton of sugarcane produced, resulting in increased production costs for the sugar mills. Furthermore, it was found that some farmers feel the need to burn sugarcane before harvesting, fearing that their sugarcane might catch fire from neighboring fields or due to unauthorized burning. Therefore, they decide to burn their sugarcane based on the preferences of the majority.

6) Government measures to address the issue of sugarcane burning have shown that every farmer is aware of the government's efforts to tackle the problem. Farmers possess knowledge, understanding, and awareness of the issue and the impacts of burning at a certain level. However, some farmers continue to choose burning as their preferred method due to placing greater emphasis on the reasons mentioned above. Furthermore, farmers perceive that the immediate effects of particulate matter (PM 2.5), smoke, and other pollutants resulting from burning do not have an immediate impact on health and the environment. Although there may be ash or black snowfall in some areas where sugarcane is burned, these elements are washed away and do not cause prolonged inconvenience or adverse effects.

A significant finding is that every farmer is aware of the laws prohibiting burning in open areas, yet there have been no reported cases of legal prosecution for clandestine burning. Instead, compensation has been provided to owners whose fields have been damaged by the spread of fire from neighboring plots. Additionally, it was found that most farmers are satisfied with the rate of compensation for burned sugarcane at 30 baht per ton, but they are dissatisfied with the rate of compensation for manual harvesting, which is 120 baht per ton. Farmers justify this by considering it an unreasonable rate and an unsustainable solution. The government's implementation of a project to assist sugarcane farmers in harvesting high-quality fresh sugarcane to reduce PM 2.5 emissions has been carried out on a yearly basis, lacking continuity. Therefore, if the government intends to encourage farmers to change their harvesting practices to eliminate burning, it should establish a fair purchasing price guarantee for fresh sugarcane to instill confidence and motivation among sugarcane farmers. Naphasom Sinpermsuksakul (2019) suggested that the government should increase the rate of compensation for burning from 30 baht per ton to 68 baht per ton, with shared responsibility between farmers and sugar mills, and allocate the average amount

of money obtained from this increase to farmers who sell freshly harvested sugarcane. This approach would incentivize farmers to reduce burning in their fields.

6.4.2 Causes and Conditions for Sugarcane Leaf Burning After Harvest

The main reason farmers burn sugarcane leaves after harvest is to clear the field and prepare the soil for the next production season. Although there are several methods to remove sugarcane leaves from the field, burning is considered the easiest, most convenient, and cost-effective method. However, burning sugarcane leaves before soil preparation has various negative impacts, such as the destruction of organic matter and nutrients in the soil. This leads to increased production costs due to the loss of beneficial elements for plants, as well as the disruption of beneficial insects and microorganisms in the soil (Sanglha, 2005; Wunprasert & Keothai, 2015; Ketjoi et al., 2021). Some farmers choose to plow under or sell the sugarcane leaves to biomass power plants, depending on certain conditions, including:

1) Field preparation for replanting: It is found that small-scale farmers who have the final crop cycle and need to replant sugarcane burn the leaves to clean the field and prepare it for new varieties. However, large-scale farmers with machinery use the method of using sugarcane leaves as mulch and plowing them under to enrich the soil for new sugarcane cultivation.

2) Costs of managing sugarcane leaves, returns received, and machinery: Farmers who utilize sugarcane leaves as mulch without burning them or selling them argue that in the 2021/2022 production season, they were impacted by the increased fertilizer prices, as well as other production factors such as weed control, pest control, and oil costs. Therefore, they choose to use sugarcane leaves as mulch to enhance soil fertility, reduce fertilizer costs, maintain soil moisture, conserve water, prevent weed growth, preserve beneficial microorganisms and insects, and prevent stem borers. This practice results in healthier and more productive emerging sugarcane plants. These farmers have access to machinery for plowing under the leaves, while some farmers without equipment prefer to burn the leaves as before. Additionally, farmers who sell their leaves to pressing contractors receive compensation and do not incur expenses for removing the leaves from the field.

3) Purchasing outlets and the number of leaves pressing machines: In some areas, farmers want to sell their sugarcane leaves, but they cannot find buyers or have to wait a long time for the leaf pressing machines. This situation increases the risk of fire burning the newly emerging sugarcane in the field, causing damage. Consequently, it becomes necessary to burn the discarded leaves.

4) Promoting leaf purchase to increase income and reduce post-harvest leaf burning by the government: Some farmers are not aware that the government encourages biomass power plants to purchase sugarcane leaves. This initiative is mostly aimed at small-scale farmers with limited cultivation areas who sell fresh sugarcane at collection points or sell it to quota leaders. After participating in group discussions, farmers have gained knowledge about better leaf management practices. They express their desire to sell leaves to willing buyers, as it generates income and adds value to agricultural byproducts, in line with the research conducted by Boonyakunakorn et al. (2021). Their findings show that revenue from selling electricity generated from sugarcane leaves could reach up to 23 billion baht for 10 million tons of leaves, while also contributing to environmental sustainability by reducing PM10 pollution, estimated to have a value of up to 160 billion baht.

7. Conclusion and Recommendations

This study has found that the causes and conditions leading to sugarcane burning by farmers, both before and after harvest, result from several factors. The most influential factors affecting burning behavior can be ranked as follows: high costs of cutting fresh sugarcane, labor shortage for cutting sugarcane, unsuitable terrain for using cane-cutting vehicles, insufficient number of cane-cutting and leaf-pressing vehicles, farmers lacking cane leaf shredding machines, preference for sugarcane burning in the area, government's insufficiently motivating measures to address the sugarcane burning issue, and farmers' lack of sugarcane buyers.

Furthermore, it was observed that most farmers are aware of the health impacts of sugarcane burning and have benefited from the government's measures to address the issue. However, they still continue burning sugarcane because farmers prioritize the returns from burning over the immediate health effects of PM 2.5. Additionally, it was found that deducting 30 baht per burned ton of sugarcane and paying 120 baht per fresh-cut ton of sugarcane did not motivate farmers to change their burning behavior.

Although the government has implemented various measures to tackle the issue of sugarcane burning, it was found that some farmers in certain areas still burn sugarcane before harvest, as reflected in the amount of burned sugarcane in each production season that does not meet the government's targets. This indicates the inability of stakeholders, including sugarcane farmers, sugar factories, and the government, to collaboratively address the

root causes and constraints. The targeted approach to problem-solving should be expedited by creating incentives for farmers to increase the supply of fresh-cut sugarcane to factories. This can be achieved by appropriately determining the rate of deducting compensation for burned sugarcane to compensate farmers who cut fresh sugarcane, which incurs higher costs than burning sugarcane. Consequently, farmers who cut fresh sugarcane would have higher total income compared to those who burn sugarcane.

In addition, sugar factories should prioritize the ranking of purchasing fresh-cut sugarcane over burned sugarcane. Government agencies should focus on research and development of small-scale, affordable machinery and equipment suitable for farmers' contexts to compensate for labor shortages. This would enable farmers to easily access services at low costs. Furthermore, it is important to establish a learning process for farmers to adopt technology and enhance their preparedness for behavior change towards not burning sugarcane. This can be achieved by creating awareness of the health impacts of burning sugarcane for both individuals and the community through a combination of social and legal measures.

Acknowledgments

We would like to thank the editorial team of International Business Research who took the time to participate in this study.

Authors contributions

Dr. Sudarin Rodmanee was responsible for the whole paper. Mrs. Aeumporn Loypradit and Mis Chiraphorn Parnporm were responsible for part of the literature reviews and also approved the final manuscript.

Funding

Not applicable

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

References

- Boonyakunakorn, P., Reukamnuaychok., Nualyai, P., Preukdee, S., Srikongpetch, K., & Wangwanichphan, S. (2021). *Sustainable sugarcane burning solution and motivation enhancement*. Retrieved from https://www.bot.or.th/Thai/MonetaryPolicy/ArticleAndResearch/FAQ/FAQ_188.pdf
- Department of Pollution Control. (2020). *PCD jointly suspends burning of sugarcane and sugarcane fields to mitigate PM 2.5 dust in the Northeast region*. Retrieved from https://www.pcd.go.th/pcd_news/10806
- Ditkamol, T. (2008). Utilization of bagasse for sugarcane production to reduce environmental pollution: A case

- of first-year sugarcane planting. *Rangkhambhaeng Research Journal, Science and Technology Edition*, 11(1), 11-29.
- Kamlha, N. (2020). *Outstanding research achievements of the Field Crop and Energy Crops Research Institute*. Retrieved from <https://www.doa.go.th/fcri/wp-content/uploads/2020/resaerch/resaerch63/R-1-4.pdf>
- Ketjoi, S., Thasa, W., Rai-Songwon, S., & Ketjoi, S. (2023). Impacts of sugarcane leaf burning on PM 2.5 pollution in sub-districts of Muang District, Wiang Kao Sub-District, Khon Kaen Province. *Journal of Buddhist Education and Research*, 7(1), 16-25.
- Kong-on, C., & Borisut, Y. (2013). Factors influencing the harvesting behavior of farmers using pre-harvest burning methods in Nampung District, Khon Kaen Province. *Agricultural Science Journal*, 44(2), 61-64.
- Lhuengvilai, W. (2015). *Labor management problems of sugarcane entrepreneurs in Nakhon Pathom Province* (Master's thesis), Department of Business Administration, Faculty of Business Administration, Silpakorn University, Thailand.
- Meepunya, C., & Chanthakul, J. (2014). *Economic study of sugarcane factories in Amphoe Wichian Buri, Phetchabun Province* (Bachelor's thesis), Natural Resource and Environmental Study, Department of Geography, Faculty of Agriculture, Naresuan University, Thailand.
- Mheunmee, S., & Butrdee, S. (2021). Health risk assessment from PM 2.5 dust exposure in industrial areas of Pluak Daeng District, Rayong Province. *Naresuan University Journal: Science and Technology*, 14(3), 95-110.
- Mitrphol Modern Farm. (2021). *Winess Formula for Beautiful Sugarcane*. Retrieved from <http://www.mitrpholmodernfarm.com/news/2021/07>
- Nualyai, P. (2019). Why burn sugarcane. *Prachachat Online*. Retrieved from <https://bit.ly/2vD5wmd>
- Office of Agricultural Economics. (2022). *Major agricultural products and trends in the year 2023*. Bangkok: Office of Agricultural Economics.
- Office of Cane and Sugar Management. (2022). *Nationwide report on sugar production for the 2023/2024 production year (Final version)*. Bangkok: Office of Cane and Sugar Management.
- Office of Cane and Sugar Board. (2022). *Project to assist sugarcane farmers in harvesting high-quality sugarcane to reduce PM 2.5 dust during the 2023/2024 production season*. Bangkok: Office of Cane and Sugar Board.
- Phoem, S., & Saenglersawai, S. (2016). Willingness to accept price differentials of sugarcane purchased by farmers in Suphanburi Province. *Journal of Economics and Public Policy*, 7(13), 20-37.
- Sakul-Ariyakit, S., Thawornphreuk, S., & Jitmat, N. (2021). Using the DSSAT crop model to assess soil productivity for sugarcane cultivation in Saraburi Province. *Journal of Agricultural Sciences*, 52(1), 32-45.
- Sanglha, L. (2005). Impacts of sugarcane leaf burning and corrective measures. *Journal of Environmental Management*, 2(1), 1-9.
- Sinpermsuksakul, N. (2019). *Policy alternatives project to solve the problem of pre-harvest sugarcane burning*. Bangkok: National Research Council Office.
- Suchaoint, W. (2019). *PM2.5: Impacts on health and toxic mechanisms*. Retrieved from <https://e-library.siam.edu/e-journal/article/wongsakorn-sucha-in-2562>
- T. K. Equipment Co., Ltd. (2022). Small-sized sugarcane harvester CH330. Retrieved from <http://www.tkequip.co.th/products/id/148110337589836201>
- The Isaan Record. (2019). *Smoke pollution from sugarcane burning: Don't blame farmers alone*. Retrieved from <https://theisaanrecord.co/2019/12/27/pollution-burning-sugar-cane>
- Wunprasert, S., & Keodthai, T. (2015). *Land and water management for increasing sugarcane yields in the Northeastern Region* (Research Report). Crop Production Technology Department, Faculty of Agricultural Technology, Suranaree University of Technology, Thailand.