

INSIGHTS INTO THE IMPACTS OF COVID-19 AND CLIMATE VARIABILITY ON GEOGRAPHICAL INDICATION (GI) PRODUCTS: SUSTAINABILITY CHALLENGES IN THAILAND

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Abstract: Geographical Indications (GIs) are increasingly crucial in global markets as they signify quality, authenticity, and regional identity, bolstering local economies and aligning with the Sustainable Development Goals (SDGs). This study examined the concurrent impact of COVID-19 and climate variability from 2020 to 2022 on 75% of GI-certified products (118 of 158 products) across Thailand, using a mixed-methods approach (e.g., surveys and interviews). The impacts and coping responses to these challenges were summarised while also providing insights into the future of GI handling from the local producers. This includes increasing GI awareness, improving production practices, adding value, diversifying income sources, and prioritising environmental conservation. These plans were reviewed for their potential to jeopardise GI certification status or deviate from the GI sustainability framework. The sustainability of many GI products in Thailand appeared to be at significant risk. Notably, by examining both immediate challenges and long-term sustainability, the research could offer valuable insights for policy recommendations and practical solutions that support the preservation of traditional products and the sustainable development of Thai agriculture. Accordingly, the findings can have broader relevance to countries with similar agricultural dependencies, particularly in Southeast Asia or regions, where GI products are essential to the economy and cultural identity.

Keywords: Geographical indication, sustainability, GI Thai, climate variability, COVID-19.

Introduction

Geographical Indications (GIs) are governed by the Geneva Act of the Lisbon Agreement on Appellations of Origin, originally established in 1958 and revised in 2015 to encompass GIs. The World Intellectual Property Organisation (WIPO) and the World Trade Organisation (WTO) oversee GIs under the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). This framework safeguards GIs as marketing tools to conserve and promote specific products. In particular, the GI logo serves as a symbol identifying product characteristics intrinsically linked to their place of origin. The recognition of GIs enhances consumer trust in

and differentiation of high-quality products while enabling manufacturers to market them more effectively. Accordingly, the GI registry lists things that are either being considered for or have been awarded GI status, occasionally known as GI-certified, GI-labelled, GI-tagged products, or simply GI products, as used in this study. Thus, to preserve the reputation and distinguishing characteristics of premium goods from a certain region, producers must manage the resources that shape their products, notably natural and agricultural. This management is an economically necessary moral imperative to safeguard the environment. Furthermore, the

long-term production of these commodities, as well as the social and economic well-being of the people that generate them, require effective and sustainable land and natural resource management techniques (Gocci & Luetge, 2020; Goudis & Skuras, 2021; WIPO, 2021; FAO, 2023).

Climate change has significantly impacted human life in recent decades, resulting in climate variability and extremes such as floods, droughts, and storms. Consequently, these changes have notably affected the characteristics, quality, quantities, and production areas of GI products (Euromontana.org, 2016; Nuary *et al.*, 2019; Purba *et al.*, 2019; Milano & Cazella, 2021; Vandecandelaere *et al.*, 2021; Xian *et al.*, 2022; Borghini *et al.*, 2023; Henry, 2023). Concurrently, the onset of the COVID-19 pandemic in late 2019 exacerbated global health concerns, leading to the widespread implementation of restrictive measures. These policies profoundly affected various industries, particularly agriculture and food supply networks.

Additionally, social distancing, quarantines, travel restrictions, limited market hours, and prolonged government-mandated lockdowns forced the closure of industries, department stores, restaurants, and food stalls. This, consequently, disrupts the supply chain from farmers and GI producers to consumers (Benton, 2020; Holleman *et al.*, 2020; Siche, 2020; Štreimikienė *et al.*, 2021; Dudek & Śpiewak, 2022; Sridhar *et al.*, 2023). During the pandemic, the manufacturing, cost, and distribution of GI products declined (Vidaurreta *et al.*, 2020; Mishra, 2021). The combined challenges of climate variability and the COVID-19 pandemic have exposed new vulnerabilities within global agricultural sectors and food supply systems (McDougall, 2021; Rasul, 2021; Paudel *et al.*, 2023).

Despite this, research into the effects of the pandemic and climate variability on GI products remains limited. Therefore, further investigation into the diverse aspects of GIs, encompassing a wide range of product types and stakeholders,

particularly in developing countries is essential for enhancing understanding and sustainability. Among Association of Southeast Asian Nations (ASEAN), enhancing regional mechanisms to support asset creation and the commercialisation of GIs is a strategic objective of the ASEAN Intellectual Property Rights (IPR) Action Plan 2016-2025. In recent years, there has been a notable rise in the registration of GIs across ASEAN nations, with Thailand in particular achieving its target of having at least one GI per province (WIPO, 2009; Crescenzi *et al.*, 2021; WIPO, 2023).

The identified gap in the literature includes a small number of case studies investigating the dual impact of climate variability and the COVID-19 pandemic on GI products and a lack of diversity in GI case studies. This includes insufficient ground-level research from a producer-centric perspective, particularly in ASEAN countries. As such, this study seeks to close a major chunk of this gap. In line with this, this study aimed to investigate the impacts of the COVID-19 pandemic and climate variability on GI products in Thailand, as well as the responses of producers to these challenges.

Rather than concentrating on a single product, a range of GI products across Thailand was examined to broaden the national level, categorising them based on their condition and shelf life, specifically fresh, unprocessed, or perishable items versus Processed Products (PPs) with extended shelf lives. Drawing from the experiences of these concurrent impacts, this study summarised producers' perspectives on expected future GI handling, framed within the context of GI sustainability.

Here, sustainability refers to maintain the status and distinctive characteristics of registered GI products. The insights shared by GI producers were categorised and short- and long-term strategies for GI sustainable planning were proposed. Considering climate change, the possibility of future pandemics, and global economic swings, implementing a strong system for sustainable GI protection will considerably benefit rural economies by

creating decent jobs and decreasing poverty. This, in turn, assures food security and promotes social justice. As a result, GIs contribute to Sustainable Development Goals (SDGs) such as SDG 1 (No Poverty), SDG 2 (Zero Hunger), and environmental or climate action (SDGs 13 and 15), to name a few (WTO, 2023). Subsequently, the findings were translated into actionable recommendations for policymakers, producers, and other stakeholders in the GI product sector, encompassing both short- and long-term policies as well as Key Performance Indicators (KPIs). Note that the findings are valuable for Thai policymakers and other countries, particularly those within the ASEAN region, which share similar geographical, cultural, and agricultural products such as rice, durian, coffee, and pepper, amongst others.

Study Area

Thailand boasts a wealth of high-quality local products, each reflecting the unique characteristics of its regions. The Geographical Indications Protection Act was enacted in 2003 and effective in 2004. Unlike in some countries such as those in the European Union, Thai producers are not required to form associations for GI registration. Instead, they often collaborate informally within community associations. Once registered, a GI in Thailand does not expire. However, the use of the GI logo must be renewed every two years. As of September 2024, the Department of Intellectual Property (DIP) has registered 212 GI products from all provinces, categorised into rice, food, vegetables and fruits, fabrics (silk and cotton), handicrafts, and wine and liquor (DIP, 2019; 2024).

Thailand, located in Southeast Asia is bordered by diverse land and water areas and comprises 77 provinces (changwat). The country features six distinct terrain types:

- Northern Highlands: High mountains and plains bordering Myanmar, comprising nine provinces.
- Northeast Korat Basin: Characterised by rolling hills and shallow lakes draining into the Mekong River, encompassing 20 provinces.
- Central Sediment Plains: Known as the “rice bowl”, it is dominated by the Chao Phraya River and includes 22 provinces such as the Bangkok Metropolitan Area.
- Western Mountains and Plains: Narrow, sparse plains amidst prominent mountains along the border with Myanmar, consisting of five provinces.
- Eastern Coastal Mountains: Mountainous and coastal plains bordering Cambodia, comprising seven provinces.
- Southern Coastal Regions: Mountains, plateaus, coastal plains, and islands bordering Malaysia, consisting of 14 provinces.

In lowland or flood-prone areas, particularly near rivers, rice paddy soils thrive while well-drained soils on hillside slopes are used for field crops and fruit orchards (NECTEC, n.d.).

From 2020 to 2022, Thailand faced significant challenges due to the COVID-19 pandemic and climate variability, resulting in notable fluctuations in rainfall. The following summarises key data (Senate Committee on Agriculture and Cooperatives 2020; Department of Disease Control 2020; 2021; National News Bureau of Thailand 2022; Ministry of Public Health 2022; National Agricultural Big Data Centre 2023; National Hydroinformatics Data Centre, n.d.; Thai Meteorological Department, n.d.).

Rainfall Variability:

- 2020:
 - Annual Rainfall: 1,527 mm, which is 6% less than the reference level of 1,623 mm.
 - Drought Impact: Over 2,840 square kilometres of agricultural land were affected, primarily impacting rice paddies in the Northeast region.

- Economic Loss: Estimated at USD239 million.
- 2021:
 - Annual Rainfall: 1,759 mm, which is 9% higher than normal.
 - Flood Impact: 2,150 square km of agricultural land, predominantly rice paddies, and croplands in the Northeast, North, and Central regions were affected by floods.
 - Economic Loss: Estimated at USD150 million.
- 2022:
 - Annual Rainfall: 2,011 mm, representing a 23.5% increase over normal levels.
 - Flood Impact: Over 6,600 square km of agricultural land across 65 provinces in the Northeast, North, Central, and South regions were flooded, with rice fields in the Northeast particularly affected.
 - Economic Loss: Estimated at USD893 million.

COVID-19 Impact:

- 2020:
 - First Wave: Triggered by events in Bangkok, the virus spread to 68 provinces.
 - Economic Impact: National lockdowns, curfews, social distancing measures, and travel restrictions led to significant disruptions in agriculture and food supply chains.
 - Health Impact: Recorded 3,042 cases and 57 deaths, resulting in a case fatality rate of 1.46%.
- 2021:
 - Second and Third Waves: Driven by variants including Alpha and Delta.

- Economic Impact: Fluctuating containment measures hindered economic recovery efforts.
- Health Impact: Improved healthcare responses resulted in a lower case fatality rate of 0.11% during the Delta wave.
- 2022:
 - Fourth and Fifth Waves: The Omicron variant caused cases to surge to over 25,000 per day in April.
 - Economic Impact: Continued challenges for sectors such as agriculture persisted despite reopening efforts.
 - Policy Shift: Transitioned to manage COVID-19 as an endemic disease beginning in September 2022.

Considering the concurrent events of the COVID-19 pandemic and climate variability from 2020 to 2022, this study investigates their impacts on GI products across Thailand.

Methodology

Prior to approaching GI-certified producers, the institutional ethics committee (Reference ID: 091/2564) approved the study and participants gave informed consent to participate. Furthermore, in collaboration with local experts, purposive sampling was used to select certified producers, who engaged in GI production prior to COVID-19, throughout the pandemic (2020-2022), and during periods of climate variability.

Each product type had a representative producer and this study aimed to include at least 50% of GI-certified items in Thailand. As such, this study employed mixed methods survey research, incorporating quantitative research strategies (questionnaires with numerically rated items) and qualitative research strategies (open-ended questions) to describe and explore producer actions and perspectives on their GI products (Creswell *et al.*, 2018). Accordingly, the primary data sources were identified during

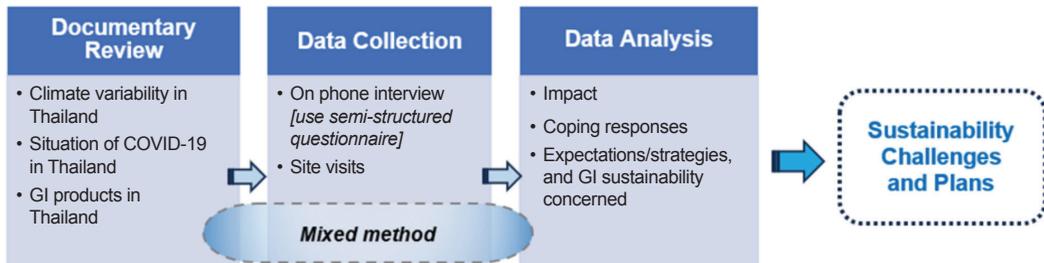


Figure 1: Research framework

the documentary review and data collection processes. The study framework displayed in Figure 1 is divided into three main phases.

Documentary Review

We reviewed three categories from different sources as follows:

- **Climate Change and Variability in Thailand:** Data from the Thai Meteorological Department and the National Hydroinformatics Data Centre were utilised to assess climate patterns and changes. Climate variability from 2020 to 2022, which resulted in significant fluctuations in rainfall is summarised in the Study Area section.
- **COVID-19 Situation in Thailand:** Information was sourced from the National News Bureau, the Department of Disease Control, and the Ministry of Public Health to understand the pandemic's impact. A brief overview of the situation from 2020 to 2022 is provided in the Study Area section.
- **GI Products of Thailand:** Thailand's GI products were investigated utilising data from the DIP, the Office of Provincial Commercial Affairs, and the Provincial Agricultural Extension Office. From 2020 to 2022, 158 Thai GI items were referred, including 18 registered for rice, 30 for foods, 76 for plants, fruits, and vegetables, 13 for silks and cotton, 19 for handicrafts, and two for wines and spirits (DIP, 2022). The investigation focused on products that were protected prior to the COVID-19 outbreak. Among the approved

producers (including suppliers) of each GI product category, a highly experienced producer or head of the production group in the village was selected as a case study. Correspondingly, the selected GI products were divided into two categories: (1) PPs such as rice, edibles, silks, cotton, handicrafts, wines, and spirits. Rice was the most recorded product type among the PPs and (2) Unprocessed Products (UPs) included plants, fruits, and vegetables, with durian being the most registered. Notably, PPs have a longer shelf life, ranging from a few weeks to several years, whereas UPs normally last a day to a few weeks. These conditions were considered in light of the study's consequences and reactions.

Data Collection

Telephone interviews were conducted during the COVID-19 lockdown and the implementation of social distancing measures. Site visits commenced after the lockdown, coinciding with improved pandemic control at the end of 2021, and continued into early 2023 to gather additional information on production practices and sites. Each producer was interviewed using a semi-structured questionnaire designed to collect three types of information: (1) The basic background of the producer and their GI products, (2) impacts and responses to the COVID-19 pandemic and climate variability from 2020 to 2022, assessed through numerically rated levels of impacts and responses, and (3) anticipated strategies for GI management in light of these concurrent challenges, which were explored through open-ended questions.

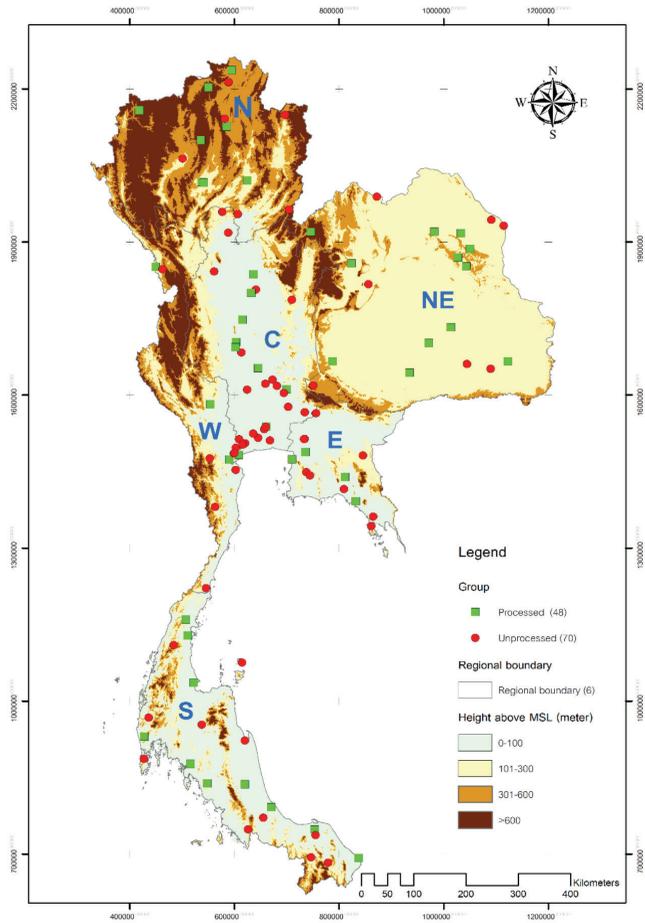


Figure 2: Representative cases of GI Thai in this study

There were 118 case studies, representing about 75% of the 158 products in the GI system were accessed. Figure 2 illustrates the distribution of these production sources across six regions of Thailand as summarised followings:

- *North (N)*: 17 products (9 PPs, 8 UPs) or about 58% of 29 total products.
- *Northeast (NE)*: 22 products (12 PPs, 10 UPs) or about 65% of 34 total products.
- *West (W)*: 10 products (4 PPs, 6 UPs) or about 77% of 13 total products.
- *East (E)*: 13 products (4 PPs, 9 UPs) or about 93% of 14 total products.
- *South (S)*: 21 products (10 PPs, 11 UPs) or about 72% of 29 total products.
- *Central (C)*: 35 products (9 PPs, 26 UPs), or about 90% of 39 total products.

The highest concentration is in Central Thailand, which accounts for the largest number of case studies. Among these, there are 48 PPs, including 14 rice products, four coffee products, various processed foods, and non-food items. Additionally, 70 UPs were examined, including 11 durians, 10 pineapples, eight pomelos, five coconuts, five mangoes, four bananas, four lychees, and other fruits and vegetables.

Data Analysis

The impacts of the COVID-19 pandemic and climate variability during 2020-2022, as derived from the case studies, were summarised and hierarchically classified. Furthermore, the coping strategies employed by households in response to these situations were listed and ranked. The expected future strategies for GI management proposed by the case studies were summarised and evaluated in the context of GI sustainability, focusing on preserving the recognised characteristics and status of GI products. However, only the impacts, responses, and expectations mentioned by at least 15% of producers were included in the results. Accordingly, the impacts and responses were rated on a five-level scale: None (0% or no impact/response), Low (25%), Moderate (50%), High (75%), and Maximum (100%).

Results and Discussion

The findings are divided into two areas: (1) Experienced impacts and coping responses and (2) future strategies concerning GI sustainability, as detailed in the following sub-sections.

Experienced Impacts and Coping Responses

- Experienced Impacts: COVID-19

The impacts of the COVID-19 pandemic on processed and unprocessed GI products in Thailand were assessed, focusing on

production and sales. These findings are summarised and presented in Figure 3 (percentage) and Appendix 1 (group of products).

- Production Impacts:* Approximately 15% of the 118 GI products (18 total: 12 PPs and 6 UPs) encountered production challenges due to supply chain disruptions and disease prevention measures. The most significant impact was noted in a processed food item from Southern Thailand (salted fish). At the same time, the West experienced the least disruption, with similar effects observed in the Central, North, and Northeast regions.
- Sales Impacts:* Approximately 78% of the products (92 total: 43 PPs and 49 UPs) experienced reduced sales volumes. This decline was attributed to fewer marketplaces and diminished demand compared to pre-pandemic levels. The pandemic shifted consumer priorities towards essential and medical products, leading to lower-cost options outpacing higher-priced alternatives. Consequently, the premium pricing of GI products did not yield the expected benefits. The maximum sales impact was noted for one UP (sapodilla from the Central region) and four PPs,

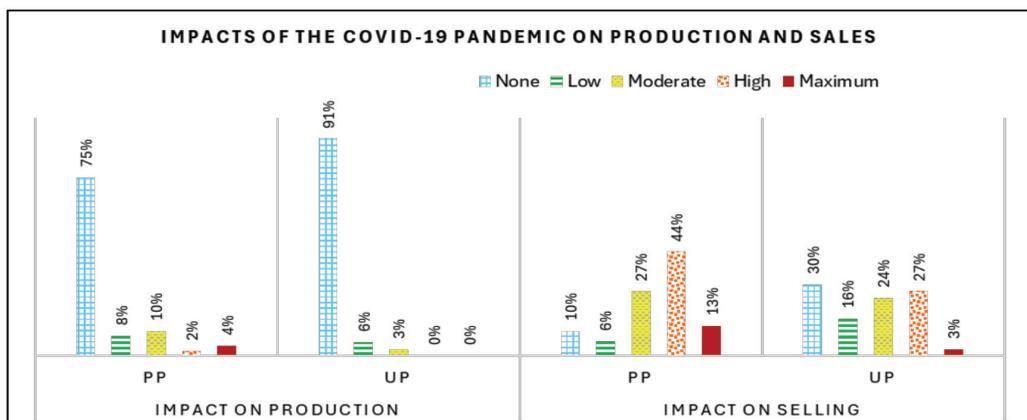


Figure 3: Impacts of the COVID-19 pandemic on production and sales

including silk yarn from the Northeast, black spinel from the West, and two food products (rice and fish) from the Central region. In addition, sales volumes for PPs in the East and West were significantly affected, with over 80% of products in other regions also experiencing declines.

- *No Impact on Production and Sales:* Approximately 22% of the products (26 total: 5 PPs and 21 UPs) distributed across various regions reported no impact on production or sales.

Overall, the pandemic had a more pronounced impact on PPs such as rice products, handicrafts, silk, cotton, wines, spirits, and certain local foods, compared to UPs, particularly durians and other fruits. Moreover, average impacts on sales and production were highest in the East and lowest in the South, with similar levels of impact observed in the Central, North, and Northeast regions.

- **Coping Responses: COVID-19**

In response to the COVID-19 pandemic, several key coping strategies emerged from 118 local producers. The strategies are listed according to their low to maximum responses in Figure 4 (with all levels of response detailed in Appendix 2) and are summarised below:

- *Production Plan Adjustments:* Approximately 50% of products (60 total: 27 PPs and 33 UPs) adjusted their production plans. Most PPs experienced moderate to high adjustments. Notably, UPs exhibited greater variability, with 10 reaching maximum adjustments, including two coconuts from the West (Ratchaburi Aromatic Coconut and Thap Salae Coconut), a coconut from the East (Bang Khla Aromatic Coconut), and several pomelos across regions. UPs that were already in the ground prior to market closures

required minimal adjustments. In contrast, those affected by pre-cropping disease control measures necessitated maximum adjustments, particularly for pineapples and shallots. Additionally, adjustments for PPs were influenced by market demand and fluctuations in raw materials, energy, and labour costs.

- *Online Marketing:* Approximately 45% of products (53 total: 22 PPs and 31 UPs) adopted online marketing strategies. Many high-demand products had pre-existing online platforms such as Thung Kula Rong-Hai Thai Hom Mali Rice (Northeast) and Sangyod Muang Phatthalung Local Rice (South), which were already registered in the European GI system. Notable examples included durian from the East (Chan Durian) and salted eggs from the South (Chaiya Salted Eggs). However, online sales constituted a smaller proportion of total revenue than onsite marketplaces. Reliance on online marketing surged during the pandemic, driven by younger workers and tech-savvy individuals returning home and engaging more with digital platforms.
- *Finding New Marketplaces:* Seeking new onsite marketplaces was employed by 22% of products (26 total: 14 PPs and 12 UPs). Only two UPs (water chestnut and sapodilla from the Central region) fully maximised this approach. High-level attempts to identify new markets were made by three products from the North (Chiangrai Tea, PP), the Northeast (Nakhonphanum Lychee, UP), and the South (Pakpanang Tabtimsiam Pomelo, UP). With traditional markets closed or operating at reduced capacity, surplus products were often redirected to smaller local markets or new intermediaries at lower prices.

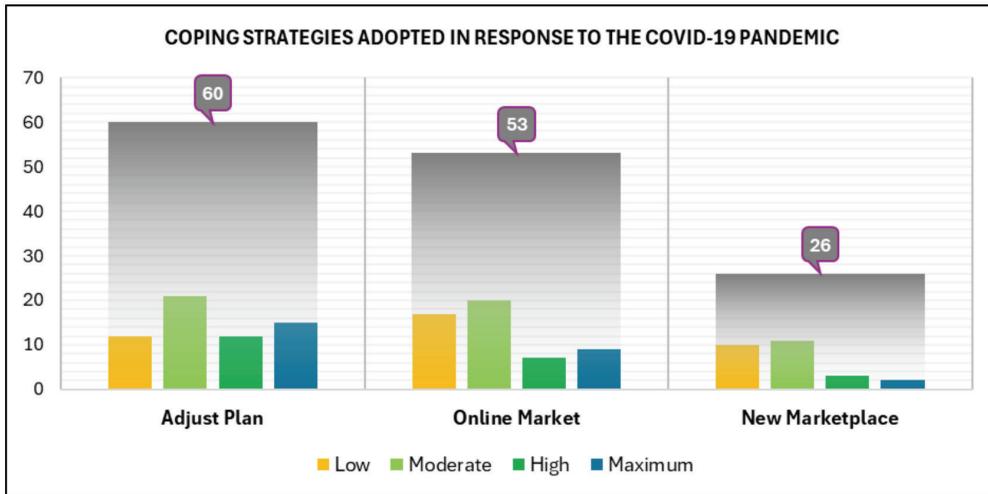


Figure 4: Coping strategies adopted in response to the COVID-19 pandemic

When comparing product types, PPs exhibited a higher response rate to coping methods than UPs across all strategies. Among the 26 products unaffected by production or sales issues, approximately one-quarter adopted coping strategies in response to the pandemic. At the same time, more than half did not implement any measures (Appendix 2). The results indicated that the level of impact on production or sales did not significantly correlate with the extent of coping actions taken. Moreover, possessing a response plan did not necessarily guarantee full mitigation of impacts.

- Experienced Impacts: Climate Variability

From 2020 to 2022, climate-related incidents affected various aspects of GI products, including production yield, quality, costs, cultivation areas, pest levels, plant diseases, and the availability of raw materials. The impacts on PPs and UPs are summarised in percentages, as displayed in Figure 5 while the level of impact of climate variability on GI production is detailed in Appendix 3. These impacts are summarised as follows:

- *Decreased Volume or Yields:* Approximately 82% of the 118 products studied (96 total: 34 PPs and 62 UPs) experienced reduced volume or yields, with UPs more severely affected. A

total of 34 GI products (10 PPs and 24 UPs) faced maximum impacts, where productivity fell below production costs. The most affected PPs were primarily processed foods from the South (e.g., coffee, velvet tamarind, dried banana, and fish), as well as rice and silk yarn from the Northeast and sugar and beans from the West.

- *Poorer Product Quality:* Approximately 75% of products (88 total: 27 PPs and 61 UPs) reported a decline in quality, with UPs again more adversely impacted. A total of 26 products (7 PPs and 19 UPs) noted maximum quality impacts. Additionally, affected PPs included three food items from the South (coffee and processed fish), rice and silk yarn from the Northeast, sticky rice from the North, and a sugar palm product from the West.
- *Increased Production Costs:* Approximately 64% of products (75 total: 26 PPs and 49 UPs) faced rising production costs, particularly among UPs. Producers of fruits such as durians and mangoes often needed to purchase water during dry spells. However, fluctuating climatic

conditions further raised costs, as many PPs relied on natural sunlight for drying. Furthermore, prolonged rain necessitated artificial drying methods and enhanced refrigeration for preservation, which added to costs. In addition, high to maximum impacts were observed across various regions, with maximum impacts affecting dried banana, sapodilla, and one handicraft product from the East.

- *Damage to Production Areas:* About 63% of products (74 total: 26 PPs and 48 UPs) experienced damage to production areas due to climate variability, with UPs being affected more significantly. High to maximum impacts were particularly noted for fruits like pomelos, bananas, and mangoes. Between 2020 and 2022, floods and windstorms caused moderate flooding, impacting paddy fields and processing sites in Central Thailand. Moreover, maximum impacts were recorded for nine products, including banana and pomelo from the Central region and rice from the North.
- *Increased Pests and Plant Diseases:* Approximately 52% of products (62 total: 18 PPs and 44 UPs) reported increases in pests and diseases, with UPs experiencing this issue more frequently. Maximum impacts were

noted for four UPs: Aromatic coconut from the East, pomelo from the Northeast, and chilli and mango from Central Thailand. This increase has also raised production costs for various fruits and rice.

- *Decreased Raw Materials:* About 33% of products (39 total: 25 PPs and 14 UPs) faced decreased raw materials, particularly affecting PPs reliant on specific inputs. This decline notably impacted handicrafts (such as mats, basketry, and dyed clothes) that depended on natural materials and processed foods like coffee and salted fish. In addition, maximum impacts were noted for eight PPs, including coffee, salted fish, velvet tamarind from the South, and rice and silk yarn from the Northeast.
- **Coping Responses: Climate Variability**

Many GI producers reported an increased frequency and severity with regard to the impacts of climate variability. However, they acknowledged that managing or manipulating natural climate conditions is extremely challenging. As a result, the “None” response was the most common among all coping mechanisms, as presented in Figure 6 (percentage). The number of products in each group and the level of responses are detailed in Appendix 4.

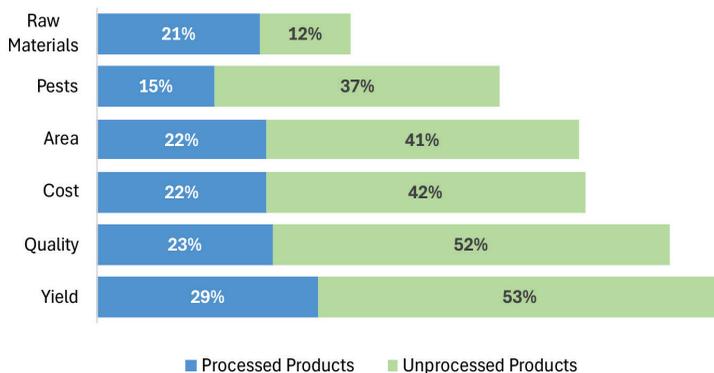


Figure 5: Climate variability on GI production of each product group

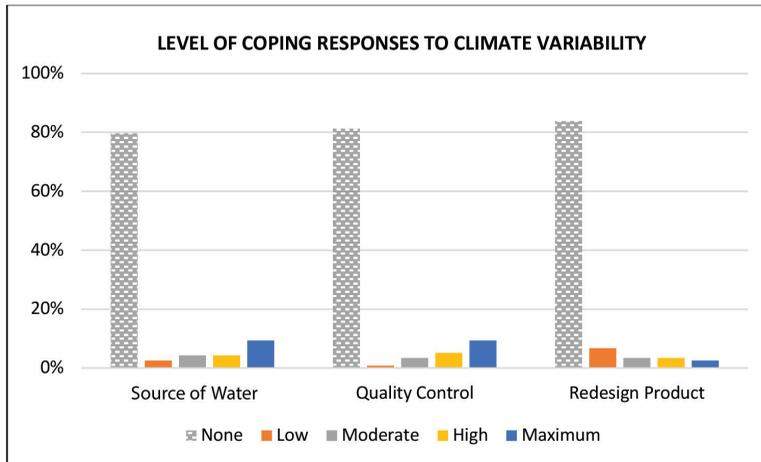


Figure 6: Coping responses to climate variability

The coping strategies adopted in response to climate variability are summarised as follows.

- *Additional Water Sources:* Approximately 20% of products (24 total: 5 PPs and 19 UPs) built additional water sources to offset drought impacts, including reservoirs and groundwater drilling. Notably, two PPs, rice from the Northeast and pepper from the South, used maximum coping methods. Among the UPs, four durians from the Central, East, Northeast, and South areas demonstrated the best coping. Other items included pomelos, tangerines, longans, and berries, and processed foods such as beef and fish used these water sources, mainly in the Northeast. Many reservoirs were built ahead of time to accommodate climate change.
- *Enhanced Quality Control:* Approximately 18% of products (8 PPs and 14 UPs) have stronger quality control methods. 11 products (3 PPs and 8 UPs) met the highest quality standards, including rice from the Central and Northeast areas, as well as pepper from the South. This group also included eight UPs: Three fruits from the Central region, two pomelos from the South, durian from the East, orange from the North, and Sakon Nakhon Mak Mao Berry from the Northeast. Notably, nine items with the greatest level of quality control included extra water sources.
- *Product Reformulation:* Approximately 16% of products (19 total: 8 PPs and 11 UPs) were altered or reformulated to address climatic unpredictability. High to maximum levels of this coping mechanism were discovered in seven products. This includes two pineapples, berries, rice products from the Northeast, tea from the North, and tamarind and sapodilla from the Central region. During some periods of fluctuating yields and market prices, many producers turned surplus or low-priced items into preserved or value-added forms. Consequently, this reformulation increased shelf life and improved internet marketing and distribution compatibility to distant markets.

- **Concurrent Impacts on GI Products**

The concurrent impacts of the COVID-19 pandemic and climate variability from 2020 to 2022 on the sales and yields of each GI product group are presented in Table 1.

Table 1: Concurrent impacts on GI products: Selling and production volume/yield

Product Group	COVID-19: Impact on Selling	Climate Variability: Impact on Volume/Yields					Grand Total
		Maximum	High	Moderate	Low	None	
PP	Maximum	1	1	2		2	6
	High	4	4	2	3	8	21
	Moderate	4	3	2	2	2	13
	Low	1	1			1	3
	None		1	2	1	1	5
PP Total		10	10	8	6	14	48
UP	Maximum	1				1	2
	High	3	1	5	1	1	11
	Moderate	6	2	5	1	3	17
	Low	7	5	6	1		19
	None	7	4	6	1	3	21
UP Total		24	12	22	4	8	70
Grand Total		34	22	30	10	22	118

Approximately 62% of the total 118 items (74 products: 30 PPs and 44 UPs) saw low to maximum levels of decreased sales as a result of the COVID-19 pandemic, as well as declines in volume or yields owing to climate variability. Among these, 23 goods (10 PPs and 13 UPs) had a high to maximum level of impact in diverse regions. In particular, the concurrent impacts were most apparent in the South (3 PPs), whereas the Central region saw the most UP fruits.

Based on producer viewpoints and experiences learnt during the COVID-19 pandemic and periods of climate variability, many prospective options for GI management are proposed and described in the following section.

The impacts of COVID-19 and climate variability on GI products in Thailand align with global trends affecting agricultural and non-food manufactured goods. Many GI products have faced fluctuating prices, limited market access, and reduced sales volumes. The pandemic primarily affected PPs, while UPs were more influenced by climate variability. Despite declining sales volumes, many UPs were sold below the GI premium and in some cases, even

beneath standard non-GI prices. Overall, GI production experienced fewer disruptions than non-GI products, which faced significant supply chain issues related to labour and raw materials, as Siche (2020) noted. Notably, over 80% of GI products relied on local labour and resources. The influx of unemployed workers returning home during lockdowns helped mitigate labour shortages, suggesting that labour scarcity did not significantly impact GI production in rural areas, particularly small-scale operations. This aligns with findings on PGI marks on lamb meat by Vidaurreta *et al.* (2020). Additionally, climate variability has affected production costs, pest management, and raw material availability, as discussed in reports by Holleman *et al.* (2020) and McDougall (2021).

Future Strategies and GI Sustainability Concerns

In this study, urgent need strategies mentioned by fewer than 15% of the 118 producers were not emphasised. The proposed strategies that are challenging to implement at both the household level and beyond are presented in Figure 7 and ranked from high to low based on voting scores as follows.

- Increase GI Awareness

Approximately 70% of the 118 GI-approved producers across all regions (83 products: 38 PPs and 45 UPs) identified enhancing public awareness of GI products as a priority for stakeholders and government authorities. Showcasing the originality and premium quality of GI products through various media to Thai and international audiences often results in higher returns. Considering the superior quality of GI products compared to non-GI alternatives, consumers are generally willing to pay a premium. Furthermore, increased awareness encourages producers to maintain high production standards. It is crucial that GI products are protected under the Geographical Indications Protection Act of 2003. Among the 83 products, many food items require greater public awareness, including 15 types of rice, six pineapples, six durians, four coffees, four bananas, four mangoes, and four pomelos. This strategy is vital for supporting GI sustainability, necessitating significant and ongoing efforts from producers and relevant authorities.

- Increase Market Channels

Approximately 64% of producers (76 products: 40 PPs and 36 UPs) across all regions proposed enhancing onsite and online market channels facilitated by government authorities. This strategy included various food products such as 15 types of rice, six pineapples, four pomelos, four coffees, three durians, three bananas, and three coconuts. In addition to establishing new market channels, many producers expressed a need for training in online marketing. While most aimed to distribute their products within domestic markets, there was interest in international markets, albeit with limited understanding. However, this strategy requires marketing expertise and suitable spaces arranged by the Department of Commerce or GI-related authorities, strengthening GI communities

and local economies, thereby benefiting GI sustainability.

- Adjust Production Practices

Approximately 51% of producers (61 products: 18 PPs and 43 UPs), particularly in agriculture, considered adjusting production practices to address climate variability. This includes modifying crop calendars or growing cycles to mitigate risks associated with dry spells, plant diseases, and pests. Among the 61 products, many food items such as 10 types of rice, nine pineapples, five mangoes, and four durians are considering adjustments, particularly out-of-season planting, to avoid surplus and low prices during regular harvest periods. However, this strategy may be unsuitable for photosensitive crops and many PPs. With increasing climate variability, some producers suggested introducing resilient plant breeds for crops like rice, pineapples, and mangoes. In line with this, cooperation among producers and agricultural experts is vital to enhance production practices, ensuring higher volume and quality. Nevertheless, adjustments conflicting with GI registration documents risk GI status.

- Add Value

Approximately 46% of producers (55 products: 22 PPs and 33 UPs) proposed adding value to GI products through innovative (attractive and durable) packaging and product reformulation. Many products, including nine types of rice, seven pineapples, and four durians, indicated a need for value addition to enhance shelf life and marketability. Thus, creative packaging suitable for delivery and appealing to modern trade or high-end markets could significantly boost producers' incomes. This effort requires expertise, innovative technologies, and substantial investment from related organisations. While developing product packaging can enhance GI marketing without jeopardising

GI status, any reform that alters specified characteristics could risk withdrawal from the GI protection system.

- **Emphasise Alternative Income Crops/Products**

Due to income instability and supply chain disruptions during the COVID-19 pandemic and climate variability, approximately 43% of producers (51 producers: 20 PPs and 31 UPs) focused on securing their incomes and overall well-being, including food security. Rather than relying solely on GI products, many producers expressed a need to explore new or alternative products to enhance their incomes. Small-scale producers planned to diversify their production to include other food crops or higher-demand products. Furthermore, the increasing registration of similar GI product types such as rice products, durians, pomelos, pineapples, mangoes, and bananas has increased producers' competition. Those producing lower-priced, less in-demand products exhibited a stronger inclination to rely on alternative non-GI products. However, reducing reliance on GI products poses a risk to GI sustainability, as the number of approved producers and the volume of GI products may gradually decline within the GI protection system.

- **Use of Innovation and Technology**

Approximately 35% of producers (42 products: 12 PPs and 30 UPs) proposed adopting automated and labour-saving innovations and technologies to enhance GI production. The following innovations were identified as necessary for supporting production:

- *Production Support:* Machines for seeding, fertilising, watering, harvesting, and pruning, as well as automatic handling systems during processing and packaging.
- *Quality Control:* Maturity detectors, refractometers for measuring fruit

sweetness, and systems for screening unqualified products.

- *Other Innovations:* Systems for disaster mitigation, pest detection, waste management, and methods to increase suitable areas for GI production, along with various creative ideas.

This strategy encompasses a range of innovations, from small detectors to large machinery, requiring expertise, and substantial funding from the government or related authorities. However, reliance on such innovations could jeopardise GI sustainability for products that depend on traditional human skills. For example, some GI registration documents specify hand harvesting and introducing harvesting machinery could adversely affect product quality.

- **Environmental Conservation**

Approximately 18% of producers (22 products: 9 PPs and 13 UPs) advocated for strategies to increase forest area, protect against forest fires, mitigate global warming, and adopt green or organic processing practices. Environmental conservation was particularly emphasised by producers whose raw materials or yields are affected by environmental conditions, including four pineapples, three coffees, two rice varieties, tea, and handicraft products (e.g., basketry, indigo dye). This strategy is beneficial for sustainable production. Nevertheless, sourcing new raw materials could pose a risk to GI status in cases of raw material scarcity induced by climate variability. For instance, if products clearly indicate the origin of their raw materials, sourcing from external suppliers could conflict with GI registration requirements.

Notably, alternative revenue crops/products, as well as the use of innovation and technology were advocated the most by producers in the Central region. However, these tactics could result in the loss of GI status. UPs

had higher expectations than PPs, particularly for changes in manufacturing techniques and the application of innovations, as displayed in Figure 7 (Innovation and Technology). However, significant disparities in the number of proposed methods were less well characterised by region and product category. Furthermore, some producers chose food security and revenue for their families over GI status, which will influence the long-term viability of GIs in Thailand.

Among the proposed future strategies from the perspective of GI producers, increasing awareness of GI products and enhancing market channels are similarly recommended in the study by Misha (2021). Effective public relations and marketing strategies should also address consumer awareness factors, as Goudis and Skuras (2021) mentioned. Furthermore, increasing the involvement of younger generations in the GI value chain and creating favourable conditions to attract them to agriculture, as Rasul (2021) suggested, would be beneficial. Notably, these strategies support GI sustainability, particularly regarding environmental conservation initiatives proposed by producers reliant on natural resources such as coffee, tea, and handicrafts. Concurrently, small-scale farmers and forest-dependent communities face heightened risks due to climate change, consistent with the findings of Holleman *et al.* (2020). This also aligns with the conclusion

by Milano and Cazella (2021) that GI serves as a complex tool for promoting sustainable territorial development.

To mitigate the impacts of climate variability, adapting agricultural practices and identifying new sources of materials or production sites are critical solutions. The implications of relocating production sites merit further investigation. Note that relocation may alleviate climate impacts. Nonetheless, it could adversely affect product quality, as noted by Henry (2023). In addition, techniques such as the Maximum Entropy (MaxEnt) model have been explored to identify suitable areas for GI products. This is by considering environmental factors to optimise site selection, as proposed by Nuary *et al.* (2019), Purba *et al.* (2019), and Xian *et al.* (2022). However, this may conflict with GI registration requirements, as suggested by Borghini *et al.* (2023). Hence, innovative technologies are essential for enhancing processing speed and quality control, yet care must be taken to preserve the traditional practices that define GI products, as emphasised by Gocci and Luetge (2020).

In Thailand, producers are not required to form formal associations for GI registration. Instead, they create informal community associations for collective registration. This contrasts with the European Union’s approach (WIPO, 2023) and warrants exploration of its

FUTURE STRATEGIES FOR GI HANDLING: PRODUCER PERSPECTIVES

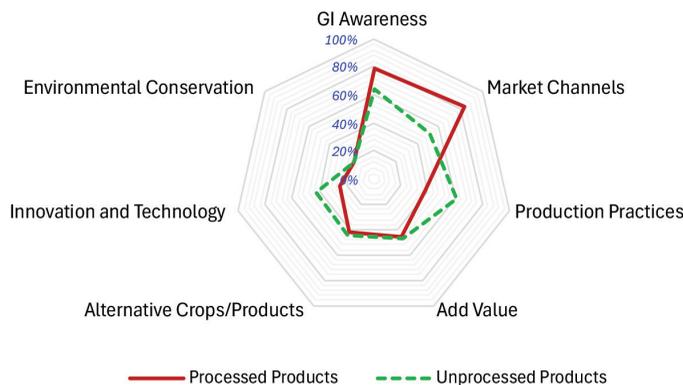


Figure 7: Future strategies for GI handling

effects on producer impacts, responses, and expectations during the pandemic and periods of climate variability. As noted by Cardoso *et al.* (2022), the challenges and benefits of GIs for producers vary regionally. Therefore, future strategies should address numerous issues within the existing GI system. Additionally, developing support mechanisms beyond registration to enhance confidence and benefits for both producers and consumers could strengthen the GI protection system and support rural economies.

Conclusions

Significant research has explored the economic impact of COVID-19 and the effects of climate change on agriculture. The intersection of these two factors in GI products, a niche yet culturally and economically significant category has been largely underexplored. Thus, this study seeks to fill this gap by examining how these dual challenges affect the sustainability of GI products in Thailand. In particular, this research addresses a notable gap in the literature, offering insights into how resilience in agriculture and the preservation of cultural heritage can be achieved in the face of global crises and aligning with several United Nations SDGs. This includes SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land), among others.

Moreover, this study employed a mixed-methods approach, combining surveys, and in-depth interviews to comprehensively analyse the impacts of COVID-19 and climate variability on GI products in Thailand. Notably, Thailand's GI products such as Thai jasmine rice, Thai silk, and specific fruits like durian are unique to the country and highly valued in local and international markets. Correspondingly, examining the intersection of GI products and sustainability challenges makes this study particularly relevant to ongoing global discussions on sustainable agriculture and food systems. As such, the study identified seven key expectations from GI producers across Thailand regarding GI management, comprising

increasing awareness, expanding market access, adopting new production techniques, and encouraging innovation. These expectations offer a roadmap for enhancing the sustainability of GI products. In line with this, the research underscores the need for collaboration between stakeholders, producers, government agencies, businesses, and specialists to address the issues identified and ensure the sustainable management of GI products.

Accordingly, the findings could provide valuable recommendations for local and national policymakers in Thailand, helping them understand the vulnerabilities of GI products and the necessary steps to support these industries in the future. Moreover, this study offers actionable insights into how agricultural producers and the GI sector could become more resilient to future shocks, whether caused by health crises (such as COVID-19) or climate-related events. While the focus is on Thailand, the findings are relevant to other countries with similar agricultural dependencies, particularly in Southeast Asia or regions, where GI products are vital to the economy and cultural identity. Nevertheless, the insights on sustainability and climate adaptation may be applicable to other countries facing comparable challenges due to climate change or the economic aftermath of the COVID-19 pandemic. Therefore, further enhancing and expanding this study are provided in the section titled "Recommendations".

Recommendations

Recommendations for Further Study

Key areas indicated for future exploration include:

- **Product specifics:** Learn more about GI products, including production methodologies, market demand levels, cropping cycles, production sizes, and GI producer profiling. This can offer information on their views of impact and coping techniques. Building on this, the successfully implemented response and coping methods are worth investigating.

- Methodology concerns: While the mixed-methods technique utilised in this study provides a complete view by mixing quantitative and qualitative data, it also introduces some problems. The findings from quantitative and qualitative data may not constantly agree. For example, quantitative data may indicate a significant impact or response to the pandemic or climate variability, yet qualitative interviews may reveal deeper issues that numerical data do not convey. Note that conciliating such disparities can be challenging and may necessitate careful interpretation.
 - Focused subgroups and time periods: To acquire more exact information on the effects of COVID-19 and climate variability, consider limiting the analysis to certain product kinds or smaller subgroups. Considering the variation in effect levels and coping practices among 118 producers from 2020 to 2022, changing the observation period to annual or quarterly intervals may be desirable for more dynamic insights.
 - Case Representation: Improve the depiction of each GI product by choosing cases from various geographical areas and manufacturing sizes. Rather than focusing just on replies from at least 15% of producers, consider all responses to allow for a thorough examination of both poor and optimal methods.
 - Comparison with other nations/areas: To increase the research's global relevance, compare the effects of these dual issues on GI products in Thailand to those in other countries or regions.
- Recommendations for Policymakers**
- Based on the shortcomings identified in this study, strategic pathways for sustainable GI planning at the national level should focus on two primary areas: Marketing and adaptation planning. Furthermore, the proposed strategies
- require cooperation among central governmental authorities, primarily the DIP, the Ministry of Commerce, and local entities such as provincial governors and agricultural offices. In addition, engaging experts from diverse fields, including agriculture, marketing, packaging design, and innovation will further enhance this collaborative effort. However, the sources and amounts of budget usage extend beyond the scope of these recommendations. The outlined strategic plans, timeframes (with short-term covering one month to less than three years and long-term spanning three to five years), and potential KPIs are as follows.
- Marketing Support Planning
 - This plan attempts to improve marketing and financial security by focusing on three key areas:
 - *Enhancing GI Awareness:*
 - Short-term: Utilise social media and influencers to market products to local and worldwide audiences. KPIs could include measurements for content development (articles, videos) and audience engagement (views, followers).
 - Long-term: Update communication plans regularly to suit new media trends and continue to publicise newly registered GI products and their benefits, tracking the success of awareness campaigns annually.
 - *Increasing Market Channels:*
 - Short-term: Establish government-approved online shops for GI producers and organise product display events. KPIs should include the number of events as well as indicators for online interaction.
 - Long-term: Establish physical retail locations for GI items, rotating stock based on seasonal availability. Annually, track the number of retail outlets and product offers for KPIs.

- *Adding Value to Products:*
 - Short-term: Improve packaging and processing procedures to improve shelf life based on market research. KPIs can include the number of new packaging designs and successful product reformulations.
 - Long-term: Continuously seek stakeholder feedback to improve packaging and processing techniques. Update GI documentation as appropriate and track successful modifications as KPIs.

- **Adapting Production Plans**

This proposal concentrates on adjustments for GI production:

- *Adjusting Production Practices:*
 - Short-term: Summarise climate-related production difficulties and engage specialists for specialised solutions. KPIs should include the identification of problems and the introduction of new procedures.
 - Long-term: Explore new agricultural techniques and technologies to improve output and productivity compared to existing standards (KPIs).
- *Using Innovation and Technology:*
 - Short-term: Form working groups to identify technology needs and use current solutions to meet specific difficulties while preserving GI status. KPIs could track progress in problem solutions and technology applications.
 - Long-term: Evaluate the impact of innovations and ensure they align with standard GI documenting methods. Track GI certification modifications and updates as KPIs.
- *Environmental Conservation:*
 - Short-term: Collaborate with local communities and authorities to

monitor environmental conditions impacting production and engage citizens in conservation initiatives. KPIs for conservation efforts should include the number of participants as well as the implementation of recovery or conservation programs.

- Long-term: Assess conservation efforts' success and effects on local habitats after three years. Set ambitious KPIs for sustainability goals.

Strengthening Thailand's GI protection system is crucial to achieving sustainability. In particular, protecting certified products from misuse or imitation of registered names must be prioritised to assure product authenticity for consumers. In addition, to effectively respond to climate change and unexpected challenges, industrial methods, practices, technologies, and approaches must be consistent with GI regulatory frameworks. Notably, GI products represent a blend of geography, culture, and economy, where the geographical location directly influences the product's identity, reputation, and value. Moreover, local producer communities regard GIs as an excellent chance to boost rural economies, create jobs, conserve cultural heritage, and encourage self-sufficiency. In other words, resident-led long-term planning for local environmental protection can boost GI production, local tourism, and regional marketing. Therefore, research on the resilience and sustainability of these products could offer useful lessons for other nations with similar dependencies on agricultural exports and traditional goods.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

- Benton, T. G. (2020). COVID-19 and disruptions to food systems. *Agriculture and Human Values*, 37, 577-578. <https://doi.org/10.1007/s10460-020-10081-1>
- Borghini, A., Piras, N., & Serini, B. (2023). Hot grapes: How to locally redesign geographical indications to address the impact of climate change. *World Development Sustainability*, 2, Article 100043. <https://doi.org/10.1016/j.wds.2023.100043>
- Cardoso, V. A., Lourenzani, A. E. B. S., Caldas, M. M., Corrêa Bernardo, C. H., & Bernardo, R. (2022). The benefits and barriers of geographical indications to producers: A review. *Renewable Agriculture and Food Systems*, 37, 707-719. <https://doi.org/10.1017/S174217052200031X>
- Crescenzi, R., De Filippis, F., Giua, M., & Vaquero-Piñeiro, C. (2021). Geographical indications and local development: The strength of territorial embeddedness. *Regional Studies*, 56(3), 381-393. <https://doi.org/10.1080/00343404.2021.1946499>
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE.
- Department of Disease Control. (2020). *Measures to prevent and control the outbreak of coronavirus 2019*. <https://ncmc.moph.go.th/home/index/detail/29762>
- Department of Disease Control. (2021). *Report on the COVID-19 situation - Wave 1-3*. <https://covid19.ddc.moph.go.th/api/Cases/timeline-cases-all>
- Department of Intellectual Property (DIP). (2024). *212 Thai geographical indication*. Assessed September 26, 2024. <https://www.ipthailand.go.th/th/gi-002.html>
- Department of Intellectual Property (DIP). (2022). *158 Thai geographical indication*. Assessed May 12, 2022. <https://www.ipthailand.go.th/en/home-eng.html>
- Department of Intellectual Property (DIP). (2019). *GI Thailand*. https://ipthailand.go.th/images/gibook/GI_Book_111.pdf
- Dudek, M., & Śpiewak, R. (2022). Effects of the COVID-19 pandemic on sustainable food systems: Lessons learned for public policies? The case of Poland. *Agriculture*, 12(1), Article 61. <https://doi.org/10.3390/agriculture12010061>
- Euromontana.org. (2016). *Mitigating climate change with geographical indications and EU quality schemes*. https://www.euromontana.org/wp-content/uploads/2014/08/2016_10_21-Article-Mitigating-Climate-Change-with-Geographical-Indications-and-EU-Quality-Schemes.pdf
- Food and Agriculture Organisation (FAO). (2023). *Using geographical indications to improve sustainability – Lessons learned from 15 years of FAO work on geographical indications*. <https://doi.org/10.4060/cc3891en>
- Gocci, A., & Luetge, C. (2020). The synergy of tradition and innovation leading to sustainable geographical indication products: A literature review. *Journal of Management and Sustainability*, 10(1), 152-161. <https://doi.org/10.5539/jms.v10n1p152>
- Goudis, A., & Skuras, D. (2021). Consumers' awareness of the EU's protected designations of origin logo. *British Food Journal*, 123(13), 1-18. <https://doi.org/10.1108/BFJ-02-2020-0156>
- Henry, L. (2023). Adapting the designated area of geographical indications to climate

- change. *American Journal of Agricultural Economics*, 105, 1088-1115. <https://doi.org/10.1111/ajae.12358>
- Holleman, C., Rembold, F., Crespo, O., & Conti, V. (2020). *The impact of climate variability and extremes on agriculture and food security – An analysis of the evidence and case studies*. Background paper for *The State of Food Security and Nutrition in the World 2018*. FAO Agricultural Development Economics Technical Study No. 4. Rome: FAO. <https://doi.org/10.4060/cb2415en>
- McDougall, D. (2021). *Double impact: COVID-19 and climate change in food and agriculture, observations and recommendations for policy-makers in Southeast Asia*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Climate Smart Land Use (CSLU) in ASEAN, GIZ Office Indonesia. <https://asean-crn.org/double-impact-covid-19-and-climate-change-in-food-and-agriculture/>
- Milano, M. Z., & Cazella, A. A. (2021). Environmental effects of geographical indications and their influential factors: A review of the empirical evidence. *Current Research in Environmental Sustainability*, 3, 100096. <https://doi.org/10.1016/j.crsust.2021.100096>
- Ministry of Public Health. (2022). *Plans and measures for managing the COVID-19 situation to become an endemic disease*. <https://dmsic.moph.go.th/index/detail/8962>
- Mishra, A. (2021). Geographical indications—Challenges and opportunities in post-COVID. *Journal of Intellectual Property Rights*, 26(March), 57-68. <https://pure.jgu.edu.in/id/eprint/367/1/JIPR2021.pdf>
- National Agriculture Big Data Center. (2023). *Open government data of agriculture 2023*. <https://www.nabc.go.th/home/ebook-detail/41>
- National Electronics and Computer Technology Center (NECTEC). (n.d.). *Thailand*. <https://www.nectec.or.th/thailand/thailand.html>
- National Hydroinformatics Data Center. (n.d.). *Thailand water situation 2020-2022*. <https://www.thaiwater.net/uploads/contents/current/YearlyReport2020/summary.html>
- National News Bureau of Thailand. (2022). 2 years, 6 months, 7 days, only COVID left: Communicable diseases that must be monitored. <https://thainews.prd.go.th/th/news/detail/TCATG220926150845084>
- Nuary, R. B., Sukartiko, A. C., & Machfoedz, M. M. (2019). Modeling the plantation area of geographical indication product under climate change: Salak Pondoh Sleman (*Salacca edulis* cv. Reinw). *IOP Conference Series: Earth and Environmental Science*, 365, Article 012020. <https://doi.org/10.1088/1755-1315/365/1/012020>
- Paudel, D., Neupane, R. C., Sigdel, S., Poudel, P., & Khanal, A. R. (2023). COVID-19 pandemic, climate change, and conflicts on agriculture: A trio of challenges to global food security. *Sustainability*, 15(10), 8280. <https://doi.org/10.3390/su15108280>
- Purba, P., Sukartiko, A. C., & Ainuri, M. (2019). Modeling the plantation area of geographical indication product under climate change: Gayo Arabica coffee (*Coffea arabica*). *IOP Conference Series: Earth and Environmental Science*, 365, Article 012021. <https://doi.org/10.1088/1755-1315/365/1/012021>
- Rangnekar, D. (2004). *The socio-economics of geographical indications: A review of empirical evidence from Europe*. International Centre for Trade and Sustainable Development (ICTSD) and United Nations Conference on Trade and Development (UNCTAD). https://unctad.org/system/files/official-document/ictsd2004ipd8_en.pdf
- Rasul, G. (2021). Twin challenges of COVID-19 pandemic and climate change for agriculture and food security in South Asia. *Environmental Challenges*, 2, 100027. <https://doi.org/10.1016/j.envc.2021.100027>

- Senate Committee on Agriculture and Cooperatives. (2020). *Report on the study on the impact on the Thai economy from the coronavirus disease (COVID-19) and recommendations to drive the development of the agricultural sector under the national strategic plan*. https://www.senate.go.th/document/Ext23868/23868842_0002.PDF
- Siche, R. (2020). What is the impact of COVID-19 disease on agriculture? *Scientia Agropecuaria*, 11(1), 3-6. <https://doi.org/10.17268/sci.agropecu.2020.01.00>
- Sridhar, A., Balakrishnan, A., Jacob, M. M., Sillanpää, M., & Dayanandan, N. (2023). Global impact of COVID-19 on agriculture: Role of sustainable agriculture and digital farming. *Environmental Science and Pollution Research*, 30, 42509-42525. <https://doi.org/10.1007/s11356-022-19358-w>
- Štreimikienė, D., Baležentis, T., Volkov, A., Ribašauskienė, E., Morkūnas, M., & Žičkienė, A. (2021). Negative effects of COVID-19 pandemic on agriculture: Systematic literature review in the frameworks of vulnerability, resilience and risks involved. *Economic Research-Ekonomska Istraživanja*, 35(1), 529-545. <https://doi.org/10.1080/1331677X.2021.1919542>
- Thai Meteorological Department. (n.d.). *Thailand weather*. <https://www.tmd.go.th/en/weather/weatherthailand>
- Vandecandelaere, E., Samper, L. F., Rey, A., Daza, A., Mejía, P., Tartanac, F., & Vittori, M. (2021). The geographical indication pathway to sustainability: A framework to assess and monitor the contributions of geographical indications to sustainability through a participatory process. *Sustainability*, 13(14), Article 7535. <https://doi.org/10.3390/su13147535>
- Vidaurreta, I., Orengo, J., de la Fe, C., González, J. M., Gómez-Martín, Á., & Benito, B. (2020). Price fluctuation, protected geographical indications and employment in the Spanish small ruminant sector during the COVID-19 crisis. *Animals*, 10(12), Article 2221. <https://doi.org/10.3390/ani10122221>
- WIPO (World Intellectual Property Organisation). (2009). *The economics of intellectual property: Suggestions for further research in developing countries and countries with economies in transition*. https://www.wipo.int/edocs/pubdocs/en/economics/1012/wipo_pub_1012.pdf
- WIPO (World Intellectual Property Organisation). (2021). *Geographical indications: An introduction* (2nd ed.). <https://doi.org/10.34667/tind.44179>
- WIPO (World Intellectual Property Organisation). (2023). *Thailand leads the way to GI registration in ASEAN countries*. <https://www.wipo.int/ipadvantage/en/details.jsp?id=12717>
- WTO (World Trade Organisation). (2023). *WTO's contribution to attaining UN sustainable development goals*. Geneva: WTO. <https://doi.org/10.30875/9789287072153>
- Xian, Y., Liu, G., & Zhong, L. (2022). Will citrus geographical indications face different climate change challenges in China? *Journal of Cleaner Production*, 356, 131885. <https://doi.org/10.1016/j.jclepro.2022.131885>

Appendices

Appendix 1: Level of impacts of the COVID-19 pandemic on production and sales

Levels of Impact	Impact on Production				Impact on Selling			
	PP	UP	Sum	%	PP	UP	Sum	%
None	36	64	100	84.75	5	21	26	22.03
Low	4	4	8	6.78	3	11	14	11.86
Moderate	5	2	7	5.93	13	17	30	25.42
High	1	0	1	0.85	21	19	40	33.90
Maximum	2	0	2	1.69	6	2	8	6.78
Sum	48	70	118	100.00	48	70	118	100.00

Appendix 2: Level of coping strategies adopted in response to the COVID-19 pandemic

Product Group	Level of Coping	Method of Coping		
		Adjust Plan	Online Market	New Marketplace
PP	None	21	26	34
	Low	3	10	8
	Moderate	11	7	5
	High	8	4	1
	Maximum	5	1	0
PP Total		48	48	48
UP	None	37	39	58
	Low	9	7	2
	Moderate	10	13	6
	High	4	3	2
	Maximum	10	8	2
UP Total		70	70	70
Grand Total		118	118	118

Appendix 3: Climate variability on GI production: Level of impacts

Product Group	Level of Impact	Impacts of Climate Variability					
		Yield	Quality	Cost	Area	Pests	Raw Materials
PP	None	14	21	22	22	30	23
	Low	6	8	7	5	5	5
	Moderate	8	2	9	14	1	4
	High	10	10	8	3	3	8
	Maximum	10	7	2	4	9	8
PP Total		48	48	48	48	48	48
UP	None	8	9	21	22	26	56
	Low	4	3	11	20	4	2
	Moderate	22	16	22	15	4	5
	High	12	23	15	8	1	7
	Maximum	24	19	1	5	35	0
UP Total		70	70	70	70	70	70
Grand Total		118	118	118	118	118	118

Appendix 4: Level of coping responses to climate variability

Product Group	Level of Coping	Coping Response		
		Source of Water	Quality Control	Redesign Product
PP	None	43	40	40
	Low	1	0	3
	Moderate	1	3	3
	High	1	2	1
	Maximum	2	3	1
PP Total		48	48	48
UP	None	51	56	59
	Low	2	1	5
	Moderate	4	1	1
	High	4	4	3
	Maximum	9	8	2
UP Total		70	70	70
Grand Total		118	118	118