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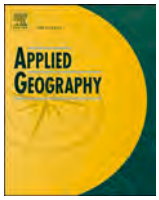

The COVID-19 Pandemic's lasting consequences for tropical crop cultivation in Eastern Thailand

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ABSTRACT

The global COVID-19 pandemic disrupted supply chains, altered market dynamics, and reshaped labor availability in agricultural communities worldwide. Today, we can begin to see some of the lasting consequences of these disruptions and farmer responses to them. This article reports on the lasting consequences of farmer adaptations to pandemic disruptions identified via in-depth interviews and farm visits in Eastern Thailand. The research team completed structured interviews with 52 farmers and 10 semi-structured interviews with key stakeholders in June–July 2024. Farmers indicated using more heavy machinery (33 % before the pandemic grew to 44 % of farmers after the pandemic) and adopting new distribution channels like e-commerce (33 % before the pandemic grew to 54 % of farmers after the pandemic). Qualitative interviews revealed further shifts including participating in cooperatives to reduce costs and maximize profits, attending more to health and hygiene practices, and pursuing crop diversification due to self-sufficiency concerns. Many of these shifts continue to be in place post-pandemic in ways that produce lasting consequences for environmental systems associated with utilizing heavy machinery, changing inputs, and diversifying crop types; social systems by shifting relations between consumers and producers and between farmers; and economic systems in the expansion of online markets and value-added goods. These findings have important implications for agricultural policy and resiliency planning, informing other regions with similar agricultural systems, and contributing to understanding of agricultural resilience, sustainable food systems, and adaptation in the face of global challenges.

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1. Introduction

In the height of the COVID-19 pandemic, news proliferated with agricultural fields lying fallow due to labor shortages, food stores closed or with empty shelves due to lockdown measures and supply chain disruptions, and ports clogged with goods waiting to pass through increased regulations at international borders (Baker & Phongpaichit, 2021). These images brought attention to the potential frailties of global food and agricultural systems but quickly faded as the world returned to a post-pandemic 'new normal'. For agricultural communities worldwide, researchers determined that the pandemic disrupted supply chains, altered market dynamics, and reshaped labor availability, but with uncertainties about the long-term implications of these disruptions (Bochtis et al., 2020; Khemanitthathai, 2021; Pimoljinda & Hongwiset, 2022). More than four years since the pandemic's onset, the lasting consequences of farmer responses to pandemic disruptions (such as utilizing more heavy machinery, diversifying crops, participating in cooperatives, and relying on e-commerce and value-added goods) can be seen in shifting environmental, social, and economic systems. This research investigated the ways in which the pandemic disrupted agricultural production, changes implemented by farmers, and the long-lasting impacts of these changes for tropical agriculture systems in the illustrative region of Eastern Thailand.

Eastern Thailand, with its fertile soil and tropical monsoon climate, produces tropical crops for Thailand, Southeast Asia, and the world. In March 2020, the prime minister of Thailand responded to pandemic threats by closing its borders to all non-citizens and declaring a State of Emergency (Ahmad & Saqib, 2022). By April 2020, the Thai government implemented strong pandemic response measures, including curfews, mandatory quarantines for international travelers, and a national lockdown. Eventually, these restrictions were lifted. However, the pandemic's overall economic and human toll was staggering, with over 4 million infections, nearly 35,000 deaths, and an economic slowdown rivaling the contractions of the 1997 financial crisis. (Ahmad & Saqib, 2022; Worldometer, 2024). It was estimated that the middle class in Thailand shrunk from 50.6 % of households to 38.4 % in the first half of 2020, with more than 8.3 million workers impacted (Ahmad & Saqib, 2022). The pandemic initially slowed manufacturing, but continued international demand for agricultural goods (especially rice, seafood, and fruit) cushioned the economic impact on the agriculture sector (Ahmad & Saqib, 2022).

This research is one part of a broader mixed methods project seeking to understand the lasting consequences of the COVID-19 pandemic on tropical crop cultivation (see Chen et al., 2024 for details on previous parts of the larger project). This portion utilizes qualitative methods to answer the research questions: what are the lasting consequences of the pandemic and climate change on tropical crop cultivation in Eastern Thailand? How have the pandemic and climate change affected the social and biophysical drivers in crop cultivation and to what effect?[1]

To answer these questions, during June–July 2024, the research team completed structured interviews with 52 farmers in Eastern Thailand, primarily in the Chanthaburi province, as well as 10 semi-structured interviews with key stakeholders in government offices related to agriculture, experts from crop-specific trade associations, and researchers focused on agricultural economics. Our research found that agricultural producers in Eastern Thailand, responded to pandemic disruptions at the national and international levels by pursuing new efficiencies on their farms (including through the increased use of heavy machinery and participating in cooperatives), seeking out new markets (especially e-commerce), and attending more to health, hygiene and crop diversification to build self-sufficiency. Many of these shifts continue to be in place post-pandemic in ways that produce lasting consequences for environmental, social, and economic systems.

This research provides insights into the physical changes in crop cultivation in the region as well as the social and economic factors influencing farmers' practices. These findings have important implications for agricultural policy, adaptation strategies, and economic planning in the region. Insights into how global events affect agriculture are valuable not only for Eastern Thailand, but potentially for other regions with similar agricultural dependencies, contributing to understanding of agricultural resilience, sustainable food systems, and adaptation in the face of global challenges. This research also contributes to literature in agriculture and food systems and the impacts of health disruptions like the COVID-19 pandemic. Literature from previous health disruptions (such as Ebola outbreaks, SARS and Avian Influenza) provide some insight, but the COVID-19 pandemic was more geographically wide-ranging and impacted many sectors, necessitating a better understanding of how changes implemented as a result of a worldwide pandemic such as this produce long-lasting impacts.

This paper will first consider the existing literature about how the pandemic impacted agricultural practices and regions as well as gaps that remain in understanding the lasting consequences of those impacts. It will then describe the research methods and site characteristics before sharing results. We conclude with a discussion about the implications of our findings and recommendations for future policy and research.

2. Review of the impacts of COVID-19 and major diseases on agriculture

2.1. Immediate impacts

The global COVID-19 pandemic produced disruptions in nearly all sectors of life throughout the world. Many food systems scholars responded quickly to consider how the pandemic was disrupting and changing food and agriculture (for example a 2020 special issue on agriculture, food and COVID-19 in *Agriculture and Human Values* published 95 articles on the topic). Researchers found that everyone from farmers to retailers and consumers were adversely impacted by local restrictions, travel bans, and market disruptions that made it more difficult to access farm inputs (including labor) and distribute farm goods (Aromolaran & Muyanga, 2020; Sharma et al., 2020; Sridhar, Balakrishnan, Jacob, Sillanpää, & Dayanandan, 2023; Stephens et al., 2022). As the pandemic stretched on, scholars continued to examine how the pandemic impacted sustainable agriculture (Marsden et al., 2023), livelihoods in farming communities (Apostolopoulos et al., 2021), civil society and food businesses (Hammelman & Turner, 2022), and the mental health of farmers (Christian Rose et al., 2023). These writings identified impacts on small-scale farming including disruptions to supply, challenges accessing markets, reduced farm incomes, limited access to labor and farm inputs, and a decline in tourism (Marsden et al., 2023).

Pandemic disruptions varied globally, with some regions hit harder across health, social, economic, and physical systems. Peripheral and rural areas faced unique challenges due to limited infrastructure and government support (Cáceres Cabana et al., 2021; Pereira Santos et al., 2024). Concurrently, scholars recognized that, as a global external force impacting human-environment relations, not all outcomes of the pandemic were negative (PiquerRodriguez et al., 2023). Indeed, as our research also shows, the pandemic eventually provided a catalyst for innovation and positive change in some sectors. While fewer studies discussed how farmers responded to these disruptions, some noted a turn to new technologies in seeking farm efficiencies and a greater reliance on digital communications and mobile phones (Marsden et al., 2023). Studies also found that farmers responded to pandemic disruptions by diversifying crop production and markets (Benedek et al., 2020;

[1] While there are overlaps between the impacts of the pandemic and climate change, we identified specific changes driven by pandemic disruptions. In order to sufficiently address both topics, we focus on pandemic impacts in this paper. Additional information about climate change impacts will be provided in forthcoming publications.

Bright et al., 2021; Goswami et al., 2021).

The pandemic greatly impacted the agricultural sector in Thailand, reducing agricultural exports by 9.37 percent within the first quarter of 2020 (Office of Agricultural Economics, 2020; as cited in Tansuchat, Pankasemsuk, & Panmanee, 2022). The lockdown resulted in decreased fruit trading volume, on-season fruit export prices, and farm-gate prices (Siriprasertchok & Panyagometh, 2020). These combined effects increased the use of online platforms, which allowed for market access and communication channels with consumers (Siriprasertchok & Panyagometh, 2020). A shift towards e-commerce enabled farmers to mitigate the effects of isolation and elevate crop sales despite limitations on transportation and communication (Chen et al., 2024; Pimoljinda & Hongwiset, 2022). The pandemic required additional standards and safety precautions to minimize the risk of spreading the disease. New procedures and health checks were implemented throughout the process of harvesting, processing, and shipping. These procedures caused delays in transit between farm and customer and increased labor demands. It was also more difficult for farmers to obtain fertilizer, pesticides, and seeds (Bochtis, 2020).

Interviews conducted by Tansuchat, Pankasemsuk, and Panmanee (2022) with fruit farmers in Chiang Mai and Chanthaburi further indicated a severe labor shortage in the agricultural sector. Transportation limitations and cross-border restrictions affected the labor markets, especially seasonal foreign harvesting workers, causing a shortage of skilled harvest laborers (Bochtis, 2020; Tansuchat, Pankasemsuk, & Panmanee, 2022). There were also restrictions at provincial borders that required additional travel authorization, severely limiting migrant labor in Chanthaburi (Khemanitthathai, 2021). Thai workers struggled to meet the demands of their farms due to family or personal illness, childcare demands, etc. The Food and Agriculture Organization completed a countrywide assessment that showed a 39 percent decrease in farm household income in the first year of the pandemic, compared to 16 percent in the general population (Udomkerdmongkol & Chalermpao, 2020). The global pandemic led to mental health challenges such as stress, depression, anxiety, and psychological distress. Farmers experienced increased stress due to isolation and negative changes in income, production, and distribution (Sapbamrer et al., 2022).

During the pandemic, the government offered relief compensation to informal workers of 5000 baht (approximately $156 USD) for three months. However, farmers experienced difficulties in receiving these relief measures due to limitations in internet access. The money required a transfer through a bank account registered by PromptPay by ID card. Those without internet access or literacy skills struggled to obtain this compensation (Sapbamrer et al., 2022).

2.2. Lasting consequences

Much less research has provided insights regarding how changes brought on by the pandemic may produce lasting consequences, despite many articles calling for consideration of how this global influence was producing long-standing changes (McKenzie & Adams, 2020). To begin to understand this, we can look to scholarship on the long-term impacts of past shocks.

Wide-spread diseases, whether pandemics or epidemics, can have lasting consequences on agricultural systems. AIDS, for example, caused around 23 million agricultural worker deaths in heavily affected African countries between 1985 and 2020 (Zhang et al., 2020), with some nations losing up to 26 % of their agricultural labor force within a few decades. Beyond the immediate death of workers, many laborers may leave the agricultural sector to take care of family members (Bell & Lewis, 2005; Zhang et al., 2020). When an epidemic remains prevalent for a prolonged period, resources will be diverted towards aiding those affected, creating potential long-term effects on the supply and skills of laborers. The loss of a knowledgeable and experienced population cannot be replaced, and those who survive may be mentally or physically impaired (Bell & Lewis, 2005). The SARS epidemic also resulted in negative labor productivity for 3–4 years after the outbreak. SARS had the greatest impact on labor-intensive industries like agriculture, while technology-dependent sectors were less affected. Though its consequences persisted beyond the epidemic, their effects fluctuated over time (Zhao & Na, 2022).

Past epidemics (including AIDS, SARS, Ebola, and Avian Influenza) led to a decline in production. Limited inputs accelerated fertilizers and machinery use. Land and labor limitations led to a modernized approach to agricultural production, because “human beings can be infected, while machines cannot” (Zhang et al., 2020, p. 421). Labor shortages pushed farmers towards mechanization and less labor-intensive crops. Changes implemented during a crisis often remain after the shock has been mitigated (Zhang et al., 2020).

Shocks on the agricultural system not only affect physical production but also the mindset and practices of consumers. During the Ebola outbreak, people were less likely to buy rice from affected areas. The Avian Influenza led to a drop in both domestic and international trade, as well as in the demand for livestock and related products. SARS resulted in panic buying due to the instability of food supply and market prices (Zhang et al., 2020). Additionally, due to the SARS' transmission pathway, international partners questioned the reliability of Southeast Asian countries as economic resources. The skepticism reduced future trade relations and undermined business confidence (Bell & Lewis, 2005).

Shocks from previous health disruptions considered in the literature were localized by region or commercial sector. The COVID-19 pandemic was more wide-ranging in geographical impact and industries impacted, resulting in policies to prevent it spreading worldwide (including lockdowns and import/export restrictions). As a result, there is a gap in better understanding the lasting consequences of the pandemic on sectors that underwent significant changes to adapt and survive disruptions. There is a need to investigate pandemic changes that remain in place or are expected to shift long-term practices. Our research seeks to fill this gap.

3. Methods

The research team utilized structured interviews (with closed and open-ended questions) with 52 farmers in Eastern Thailand; semi-structured, in-depth interviews with 10 key stakeholders in Thai government, trade organizations, and agriculture research; and 11 farm tours in Chanthaburi and Trat provinces. The interviews and farm tours enabled capturing the complex, nuanced experiences of agricultural producers and communities. Qualitative methods such as this are commonly used in the social sciences to provide explanations for trends discovered via quantitative methods, give insight into individual and group experiences, and generate theories regarding human-environment relations (Cope and Hay, 2021). This approach provided insightful contributions regarding the context and experience of farmers and the socio-economic factors impacting those experiences by allowing us to gather rich, detailed data about farmers' personal experiences, perceptions, and adaptive strategies. It also allowed us to explore unanticipated themes that emerged during conversations with farmers and key stakeholders. Participants were recruited through purposive sampling with the support of a community advisory board of agricultural experts in Thailand. In particular, we identified farmers and key stakeholders with the support of local experts, at two public events for farmers and agricultural stakeholders, and in asking for suggested contacts from interviewees. Purposive and snowball sampling are regularly used in qualitative social science research for recruiting dispersed and hard to reach populations (Hay & Cope, 2021; Parker and Scott, 2019). The multiple recruitment methods we utilized enabled reaching participants with relevant expertise and a diversity of perspectives (in terms of age, experience, crop type and farm size (see Fig. 2)). For farmer interviews, closed-ended questions inquired about demographics, crop types before, during, and after the pandemic, farming practices used before, during,

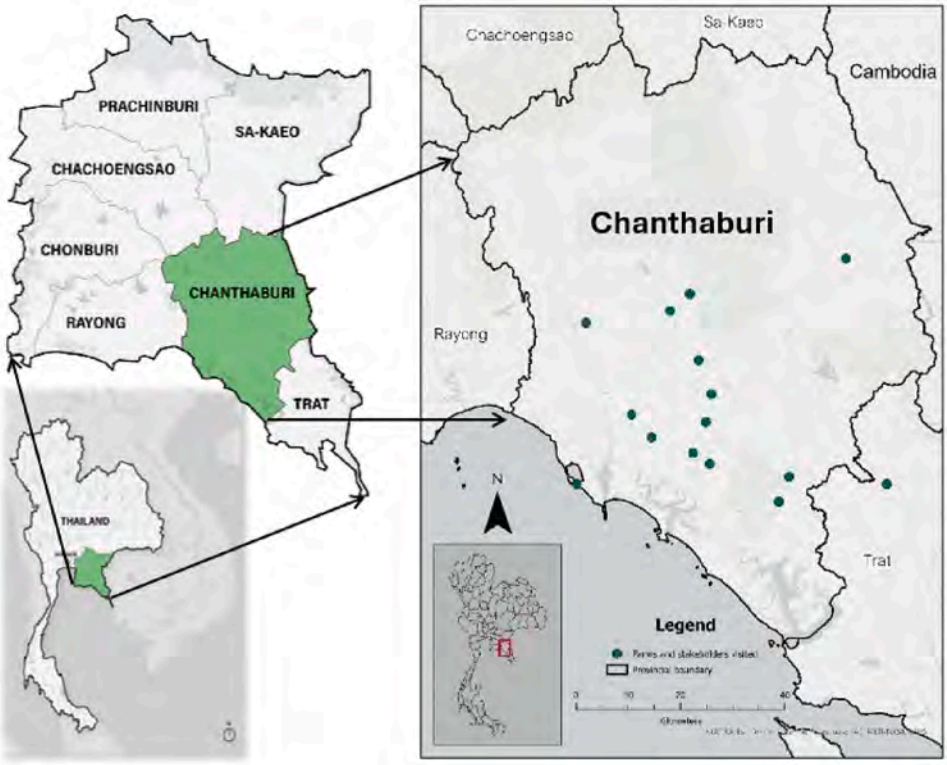

Fig. 1. Study Area: Locations of farm visits in Chanthaburi and Trat provinces in Eastern Thailand.

and after the pandemic, and markets used before, during, and after the pandemic. Open-ended questions asked farmers to elaborate on how the pandemic impacted their practices, the role of the government in mitigating those impacts, and the lasting consequences of changes brought on by the pandemic. Interviews lasted 25–50 min and were primarily conducted in Thai with an in-situ translator (except for farmers who preferred to answer questions in English). All farmers received 1000 THB to recognize the time and expertise shared with the research team.

Interviews with key stakeholders focused on their broader expertise regarding agriculture in the region due to their employment in government, non-governmental organizations, trade associations, and research. The in-depth interviews solicited information regarding the impacts of COVID-19 on agriculture in Eastern Thailand and Chanthaburi with specific attention paid to labor relations, information dissemination, government support and programs, intermediary usage, and e-commerce. Interviews lasted approximately 1 h and were completed in either Thai with interpreters or English, depending on the interviewee's preference. Several farmer interviews were conducted as part of farm visits. Visiting farms allowed the researchers to put information collected into context, providing a more complete picture of the lasting pandemic effects. On many occasions, the interviewees shared additional information during tours of their farms or through additional discussions after the interviews had concluded. These details were recorded in field notes.

All interviews were audio recorded and transcribed for analysis. All transcripts were analyzed using qualitative data analysis software, NVivo, and an iterative coding process. Using a grounded theory approach (Glaser & Strauss, 2017), the coding framework was developed iteratively, informed by existing literature (a priori codes) and themes that emerged from the data itself (inductive codes). We created a comprehensive code book that captured farmers' experiences, strategies, and challenges. These codes were organized into several broad categories, including economic drivers and consequences (e.g., changing distribution channels, labor shortages, market competition and demand), environmental drivers and consequences (e.g. decreased yield, disease, lower quality product), government-related factors (e.g., China relations, corruption, royal projects), and social and cultural drivers and consequences (e.g., mental shifts, utilizing new technologies). Each transcript was coded by three researchers.

3.1. Study site and sample characteristics

Eastern Thailand is a significant agricultural producer, supplying mainly fruits, rubber, and rice for the country and world (Chen et al., 2024). The region consists of seven provinces (see Fig. 1), displaying ecological diversity while maintaining a relatively high agricultural yield. There is also increasing urbanization pressures due to the Eastern Economic Corridor project that extends along the coasts of Chonburi, Rayong, and Chachoengsao (Tontisirin & Anantsuksomsri, 2021). The most significant crops grown in Eastern Thailand are durian, mangosteen, rambutan, longkong, rubber, and rice.

This study focuses primarily on the illustrative province of Chanthaburi, which is predominantly agricultural. It is bordered by the Gulf of Thailand to the South and Cambodia and Trat Province to the east. It is enclosed by short mountain ranges in the north. In 2021, Chanthaburi's economic activities of agriculture, forestry, and fishing contributed 74,460 million baht to the country's Gross Provincial Product via a cumulative total area of 1,699,882 rai, or 672,080 acres (1 rai = 0.39 acres) of agricultural land (Chanthaburi Provincial Statistics Report, 2023). The primary focus on Chanthaburi resulted in a sample that likely has higher-income farmers than the surrounding region, due to the higher value of durian, a prominent crop in the region. However, interviews with key stakeholders indicate that the trends identified in our research are also present in other parts of Eastern Thailand and other regions of Thailand.

Our research sample comprised 52 farmers. Of these participants, 51 (98 percent) were based in Chanthaburi, while one farmer operated land exclusively in Trat and one farmer owned land in both Chanthaburi and Trat. The sample was nearly evenly split between female (27) and male farmers (24), with 1 participant identifying as "other" (Fig. 2). The

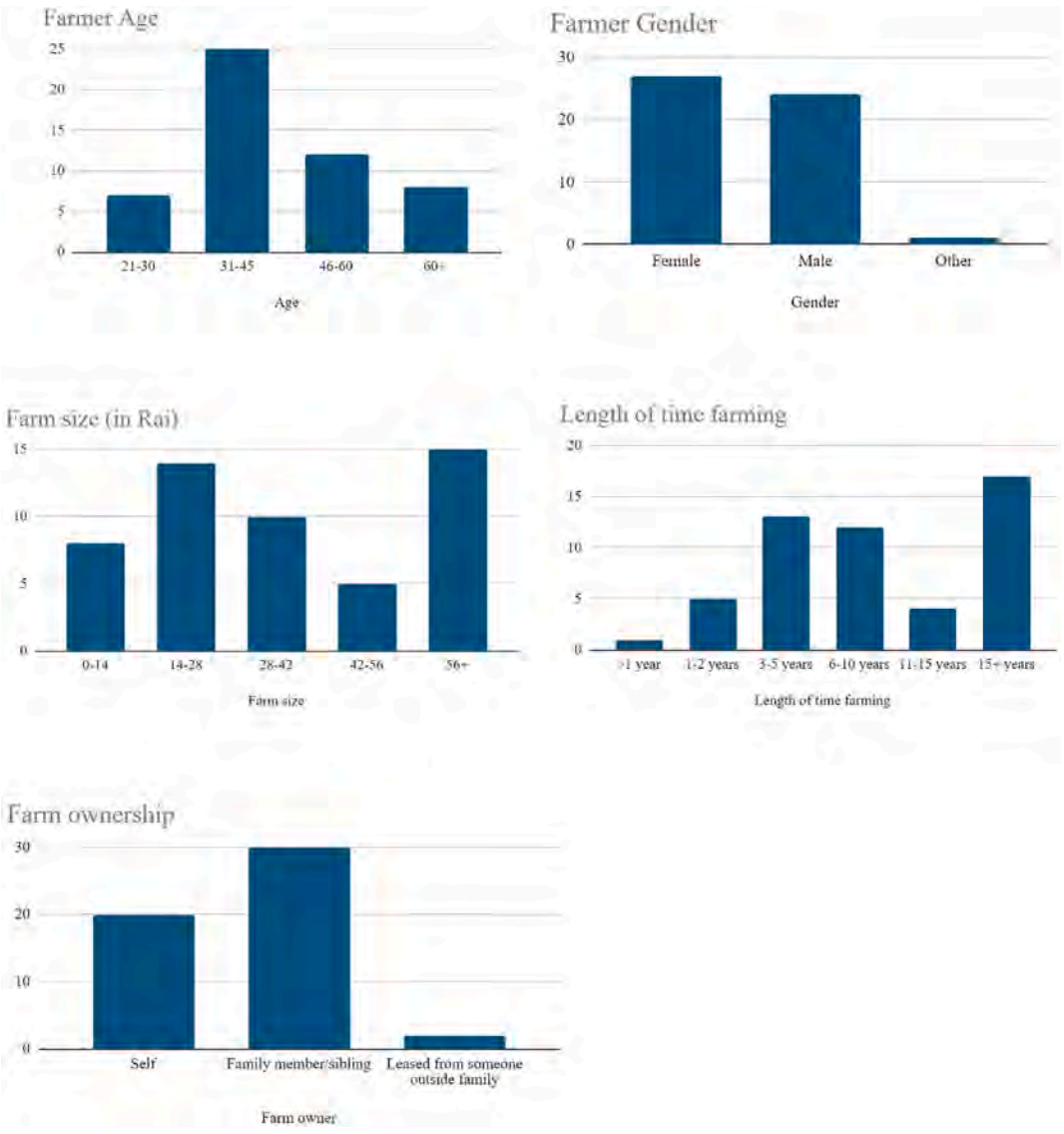

Fig. 2. Demographics of the total farmers interviewed.

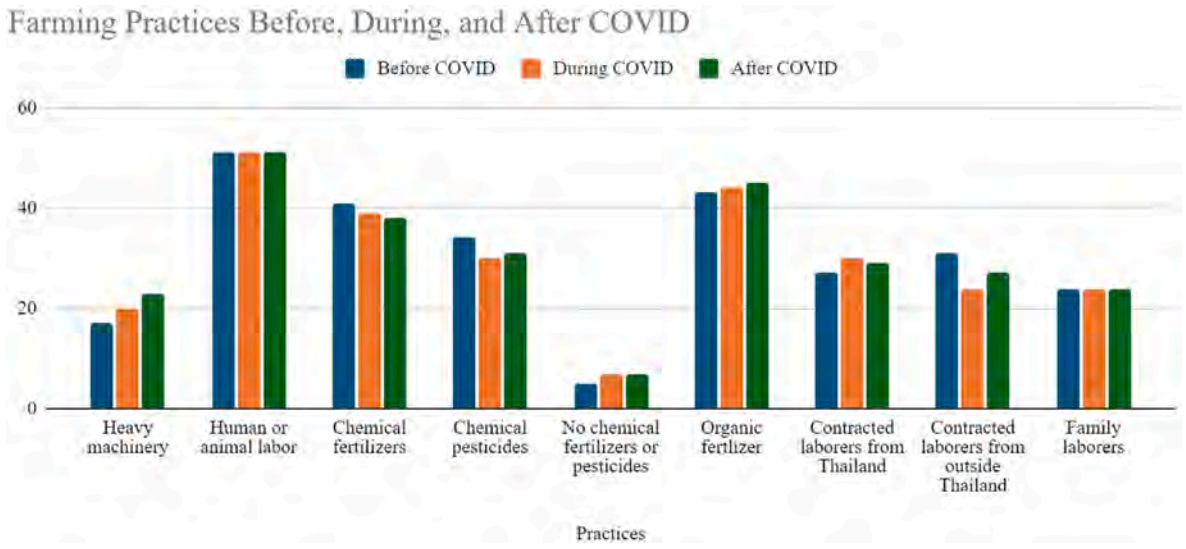

Fig. 3. Changes over time in tools and practices identified by respondents.

largest age group was 31–45 years old (25 farmers), followed by 46–60 (12), 60+ (8), and 21–30 (7) (Fig. 2). In a few instances, researchers met with multiple family members at one time, in which case the gender and age of the main respondent were recorded.

Experience level ranged from more than 15 years (17 farmers), 11–15 years (4 farmers), 6–10 years (12 farmers), to 3–5 years (13 farmers) and two years or less (6 farmers). Farm sizes varied among our participants. Twenty-two farmers operated on farms smaller than 28 rai (11 acres), 15 with medium-sized farms (28–56 rai, or 11–22 acres), and another 15 operating large farms (more than 56 rai or 22 acres) (Fig. 2). Our classification of small, medium-sized, and large farms was guided by established local traditions for farm categorization. Thirty farmers worked land owned by a family member, 20 owned their farms, and two participants leased their land from individuals outside their family (Fig. 2). This diverse sample allowed us to gather a wide range of perspectives, representing different levels of experience, age groups, genders, farm sizes, and ownership structures.

3.2. Limitations

Potential limitations of our research design include more limited generalizability from the narrow case study focus, the research team's positionality (as both international and domestic researchers), and language obstacles. First, this research focused on the Chanthaburi province in Eastern Thailand which is more reliant on durian production and the high value it garners than other regions of the country. To address this, we sought out interviews with key stakeholders that have a broader country-wide perspective. These key stakeholders validated the experiences described by individual farmers and confirmed that wider trends identified in this research are also relevant in other crop types and regions. Second, the research team was made up of both researchers from Thailand and from overseas (the United States). For the international researchers, it is possible that interview participants may be less willing to share their experiences or that nuances and contexts are misunderstood. To protect against this, each interview included at least one researcher from Thailand and one from the US, and those researchers worked together after the interviews to finalize transcripts and seek contextual and nuanced understanding. The project also relied on a community advisory board made up of Thai agricultural experts in Bangkok and Eastern Thailand. The advisory board members provided feedback on the research findings and shared additional context as needed. Finally, the international researchers did not speak Thai, which can limit understanding of interview data and hinder building relationships with informants. To address this, all interviews were translated in situ by a Thai researcher so that the US-based researchers could understand the conversation and ask follow-up questions as needed. Thai researchers also worked with the US researchers to ensure all interview transcripts were complete and accurate.

4. Results

In farmer and stakeholder interviews, participants frequently responded to the initial open-ended questions about the long-lasting impacts from the pandemic by reporting that the pandemic had little impact on them compared to the challenges they are facing in this moment from climate change. For example, one farmer (large farm, multiple crops, male) reported, "For me, the pandemic was not that bad, but climate change changed everything." Twenty-five farmers (48 percent) argued that while the pandemic impacted individuals' livelihoods and health at the moment, they were able to adapt to changes in the market and access to inputs. One farmer (small farm, multiple crops, female) explained that "farmers try to rely on themselves and adapt to various situations that arise. They focus on solving according to the situation."

However, as the conversations continued, all participants began describing changes they implemented during the pandemic that they maintain today and will continue to impact their farms into the future in meaningful ways. Among these changes were a move to more heavy machinery use and identifying on-farm efficiencies due to labor shortages, the utilization of online markets and social media in response to pandemic border and store closures, and maintaining pandemic-era health and hygiene practices and growing more diverse crop types as a result of greater concerns with health and self-sufficiency. There are overlapping impacts from the pandemic and climate change that contribute to these shifts, but our research found that most of these shifts were spurred or accelerated by specific pandemic challenges. This section describes these changes in detail.

4.1. On-farm efficiencies and new technology use

The agriculture sector in Eastern Thailand relies heavily on migrant labor from neighboring countries, such as Cambodia and Laos (Thetkathuek & Daniell, 2016). When pandemic-era restrictions limited available labor, many farmers reported needing to find alternatives and identified changes in their practices that produced efficiencies, relied less on human labor, and employed more technology and heavy machinery. Impacts were most felt from international and domestic travel restrictions, which farmers and key stakeholders explained led to shortages of quality immigrant labor and increasing costs for hiring workers. Curfews, mandatory quarantines for international travelers, and a national lockdown limited the movement and supply of international workers and increased the costs of hiring labor (Tansuchat, Pankasemsuk, & Panmanee, 2022).

Before the pandemic, 31 farmers (60 percent) in our study hired laborers from outside of Thailand. This decreased to 24 farmers (46 percent) during the pandemic and returned to 27 farmers (52 percent) following the pandemic (Fig. 3, Table 1). One farm owner (large farm, multiple crops, female) explained that the migrant workers on her farm were forced out of Thailand to renew their visas and could not return when the borders closed, leading her to find labor elsewhere. Several farmers turned to Thai laborers but reported that they were more expensive and less experienced. Before the pandemic, 27 farmers (52 percent) contracted laborers from Thailand, this increased to 30 farmers (58 percent) during the pandemic and dropped slightly to 29 (56 percent) after the pandemic (Table 1). A few farm owners described the increased utilization of illegal laborers and the cost of such labor. One farmer (medium farm, areca and mangosteen, female) reported that the expense of "smuggl[ing]" workers from Laos rose from 2000 to 10,000 baht per person. Another farm owner (large farm, multiple crops,

Table 1
Tool(s) and practice(s) identified by respondents.

Tools and practices used	Before COVID-19 pandemic		During COVID-19 pandemic		After COVID-19 pandemic	
	Count (N = 52)	%	Count (N = 52)	%	Count (N = 52)	%
Heavy machinery	17	33 %	20	38 %	23	44 %
Human or animal labor	51	98 %	51	98 %	51	98 %
Chemical fertilizers	41	79 %	39	75 %	38	73 %
Chemical pesticides	34	65 %	30	58 %	31	60 %
No chemical fertilizers or pesticides	5	10 %	7	13 %	7	13 %
Organic fertilizer	43	83 %	44	85 %	45	87 %
Contracted laborers from Thailand	27	52 %	30	58 %	29	56 %
Contracted laborers from outside Thailand	31	60 %	24	46 %	27	52 %
Family laborers	24	46 %	24	46 %	24	46 %

female) clarified that she did not use illegal labor due to insurance concerns and potential fines.

Domestic travel restrictions also created barriers to accessing labor. Checkpoints were established during the lockdown to limit the virus's spread, but they were difficult for farmworkers to navigate. The lockdown included a curfew to keep residents at home between 10pm and 5am unless they had a permission slip from a government official. A government official in charge of these permissions that we interviewed reported that she spent hours daily dealing with farmworkers' logistical concerns during the lockdown. The lockdown was especially inconvenient for many farmworkers whose crops required working at night or early in the morning. Overall, 36 farmers (69 percent) and nine key stakeholders cited labor shortages as an influential pandemic impact that led to poorer harvesting methods and a lower yield, therefore, reducing sales and revenue.

While restrictions on movement across the border and throughout the province were lifted as pandemic risks decreased, farmers and key stakeholders indicated that the costs of labor did not return to pre-pandemic levels. One farmer (large farm, bananas, male) explained that Cambodian laborers began charging the same wages as Thai farm laborers. This meant that the farm owners needed to pay each migrant farmworker an additional 50–600 baht per day. Labor agencies also began charging as much as an additional 25,000 baht to process migrant workers, due to the more complicated cross-border documentation processes, increased hygiene requirements, and the urgent demand for labor to harvest within a short seasonal window. Farm owners reported struggling to pay this price, but many wanted to continue working with the high-quality migrant workers.

Several farmers stated that they adapted to labor shortages and higher costs by relying on more advanced machinery to complete farm operations. Seventeen farmers (33 percent) employed heavy machinery for their farming operations before the pandemic. This increased to 20 farmers (38 percent) during the pandemic and further to 23 farmers (44 percent) following the pandemic (Table 1). One illustrative farmer (large farm, multiple crops, female) explained that she decided to invest in more tractors for her farm in response to challenges in securing and maintaining international laborers for her farm. For example, she invested in machinery that would cut grass faster than human labor could, thus producing new farm efficiencies. Many farmers also mentioned that they became dependent on machinery due to the pandemic and are taking measures to ensure their farms are suitable to deal with new technological advancements.

4.2. Online markets and social media

Most farmers in our research (37, or 71 percent) also reported significant pandemic impacts from market disruptions that led to pursuing online sales. During the lockdown period, many people were unable to leave their homes and maintain their regular shopping routines (Pimoljinda & Hongwiset, 2022). Farmers that we interviewed explained that customers were not going into the stores at the same rate as before the pandemic due to curfews and restrictions on border crossings that limited access to shopping malls and chain grocery stores, while outdoor markets closed or limited the number of farmers that could attend.

When farmers could not sell their products to domestic and overseas marketplaces through traditional mechanisms, many reported switching to selling their products online. In our research, only 17 farmers (32 percent) sold goods via online markets before the pandemic (Table 2). This increased by 109 percent with 35 farmers (67 percent) reporting distribution via online markets during the pandemic. One farmer (small farm, multiple crops, male) shared that since the "online market exploded" during the pandemic, he has sold more than double the amount of products than when he used traditional distribution channels. Some farmers noted that the utilization of online marketing allowed them to reach a larger audience, increasing their income. Several farmers also reported exploring new online sales and marketing strategies using Facebook, TikTok, Instagram, and other social media platforms.

Table 2
Distribution channels used by respondents.

Distribution channel	Before COVID-19 pandemic		During COVID-19 pandemic		After COVID-19 pandemic	
	Count (N = 52)	%	Count (N = 52)	%	Count (N = 52)	%
Local markets	36	69 %	34	65 %	36	69 %
Domestic markets	10	19 %	13	25 %	17	33 %
International markets	21	40 %	17	33 %	19	37 %
Via intermediaries	15	29 %	3	6 %	6	12 %
Domestic e-commerce/online	17	33 %	31	60 %	28	54 %
International e-commerce/online	0	0 %	4	8 %	6	12 %
Farmers' markets	8	15 %	8	15 %	9	17 %
Farm tourism	3	6 %	0	0 %	3	6 %
Subsistence	3	6 %	4	8 %	4	8 %
Other: Direct to supermarkets, via cooperatives, markets stalls, at festivals	4	8 %	9	17 %	9	17 %

Our research found that selling goods through e-commerce allowed farmers to expand their reach domestically and continue accessing international markets following the height of the pandemic. While some farmers returned to only using traditional distribution channels, 32 farmers (61 percent) continued using e-commerce post-pandemic (Table 2; Fig. 4). One farmer (large farm, multiple crops, female) specified that selling online increased her sales by 40–50 percent and she continued selling her products online post-pandemic because of the profitability and benefits. Another farmer (large farm, multiple crops, female) expressed that if the pandemic had not occurred and caused the market to shift, she would not have had the opportunity to learn about selling her products online. Seven key stakeholders also emphasized the new importance of online markets and digital technologies for farmers during and after the pandemic. One government official reported that due to the increased interest in online marketing, they created toolkits, websites, and other resources for farmers to further expand their online sales.

4.3. Health practices and self-sufficiency

Finally, our research found that many farmers changed their practices to protect themselves and their workers' health and to create a sense of self-sufficiency needed to protect against future disruptions. Twenty-eight farmers (54 percent) reported a shift in their thinking about health and self-sufficiency as a result of the pandemic. These farmers explained that they felt a great sense of unpreparedness and unease when the pandemic began, causing them to change their current practices. For example, one farmer (medium farm, multiple crops, male) explained that the pandemic was a very unexpected situation for which no one was prepared. But now he knows how to manage and prepare his farm for potential future disruptions.

Farm owners reported changing their practices to maintain their long-term health and the overall well-being of the farm. This included switching from chemical insecticides and fertilizers to more organic inputs. One farmer (small farm, multiple crops, female) stated that her mother is getting older, so she switched to organic products to keep her healthy. A common theme was the bioaccumulation of chemical products causing health issues.

There was also a substantial shift in hygiene practices during the pandemic. Farms were forced to change their practices to maintain a safe and clean working environment that could limit virus spread

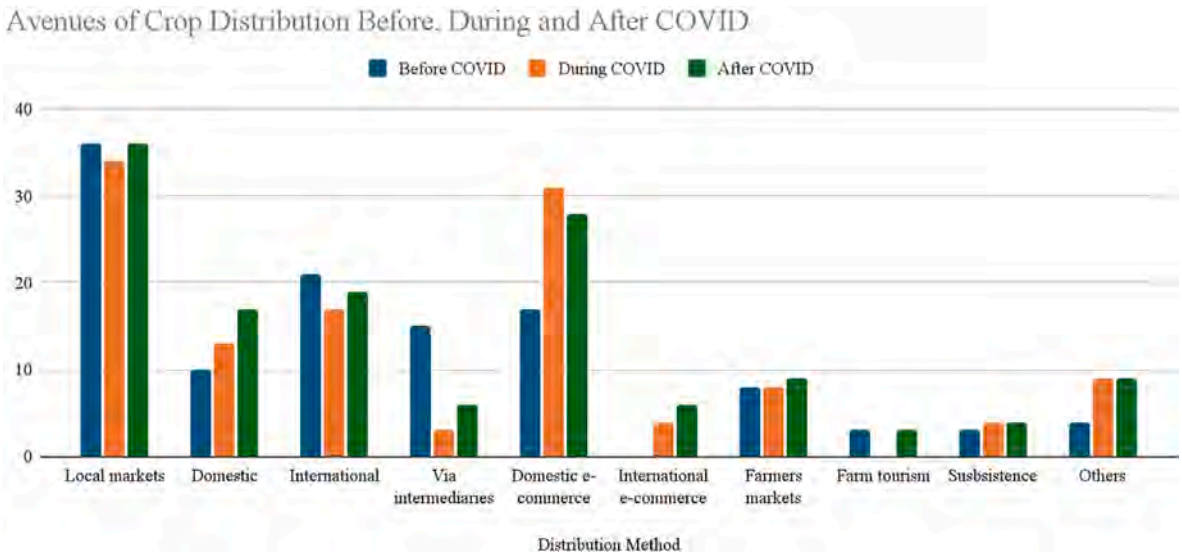

Fig. 4. Avenues of distribution identified by respondents.

(Thammachote & Trochim, 2021). Interview participants explained that while many farmworkers were naturally social distancing, this was formally instilled during the pandemic. Every step of the harvest-to-retail process was altered to maintain cleanliness standards set by the Thai government and international trade regulations. One farmer (large farm, multiple crops, female) explained that: "COVID caused farmers to be more careful with everything in the process because there is a large emphasis on ensuring everything is clean." Eight farmers described how they are continuing heightened hygiene practices even after pandemic restrictions were lifted and applying them to other illnesses like the flu.

Several farmers (16, or 31 percent) also reported pursuing more individualized coping mechanisms focused on maintaining long-term self-sufficiency including changing their crop types, growing multiple types of crops and/or developing value-added products. For example, one interviewee (medium farm, multiple crops, male) started fishing and growing vegetables to limit interactions during the pandemic. Along with this sense of self-reliance, five farmers (10 percent) and two key stakeholders explained that they have prepared more for future disasters. They did so by storing resources like water, finding new markets, and exploring value-added products such as processing fruits into other forms, including dried fruits, baked goods, juices, and fertilizers made from peels. Fifteen farmers (29 %) discussed a reliance on value-added goods, while five key stakeholders explained the importance of value-added goods for providing new revenue streams for farms during and after the pandemic. For example, one family farm determined that the large amount of durian peels produced by their farm and neighbors could be converted into fertilizer. Now, they receive deliveries of 200 tons of durian peels per year from a group of intermediaries buying fresh-cut durian. Those peels are processed over 60 days into a biofertilizer that sells for 90 THB per 20 kg bag (see Fig. 5). This process also produces fermented water that the farm then sells in a condensed form to be applied to various on-farm uses. Most farmers reported benefits from these pandemic-related changes such that they remain in place post-pandemic.

Fig. 5. A pile of durian peels being processed into fertilizer (Photo by author, 2024).

5. Discussion

Our research found that during the pandemic, many farmers struggled to produce and commercialize their crops, leading to adaptations such as introducing new machinery and technology in place of limited and/or expensive labor, utilizing online markets and social media to reach new customers, and focusing on human and environmental health and self-sufficiency through changing practices and diversifying crops and products. Participants in our research indicated that these new innovations remain in place as the height of pandemic disruptions subsides, producing long-standing shifts in environmental, social, and economic systems.

5.1. Environmental systems

Agricultural environments are changing as a result of greater reliance on heavy machinery and technology, changing inputs (such as relying more on organic fertilizers), and growing multiple crops. Our research revealed that one of the most notable impacts of the pandemic was shortages and increased costs of labor. Transportation limitations and travel restrictions affected labor supply, especially for foreign workers, causing a shortage of skilled laborers and increasing labor costs with follow-on impacts on crop production and household income (Tansuchat, Pankasemsuk, & Panmanee, 2022; Bochtis, 2020). Many farmers in our research responded to labor challenges by shifting to more reliance on machinery and digital technologies. These shifts impact the physical farm environment with multiple farmers reporting that they planted trees at wider distances or trimmed trees in order to have enough space for heavy machinery. Research also shows that implementing the use of technology can assist in reducing the cost associated with production, laborers, and fertilizers as well as increasing production efficiency (Thongkaew et al., 2021; Wetchasit & Lilavanichakul, 2023). Many farmers in our research reported that they continue to practice the adaptations undertaken during the pandemic due to the greater farm efficiencies they create.

Additionally, farmers reported that they began relying more on organic fertilizers and pesticides and began growing more types of crops in response to concerns with human health and self-sufficiency. For example, one farmer (medium farm, multiple crops, male) explained that during the pandemic he increased crop rotations, allowing him to practice planting different crops within the same field to allow it to enhance soil fertility and reduce the need for chemical fertilizers. Another farmer (large farm, multiple crops, male) now describes his farm as a "forest" due to the multiple crops he grows in alignment with the seasons and conditions of his farm. He further explained that he now prioritizes crops that grow well in a changing climate and will keep the land healthy. Similarly, researchers increasingly find that growing diverse crops and utilizing organic fertilizers can lead to beneficial long-term impacts on soil health (Assefa & Tadesse, 2019; Jiang et al., 2022). A provincial agricultural expert further pointed out that many farmers switched from mono-cropping to growing multiple crops to contribute to community food supply because "COVID taught them how to survive" (key stakeholder interview, 2024).

5.2. Social systems

We also found that social systems are changing through the forming of new or stronger relationships between farmers and consumers (via online markets), between farm owners and farmworkers (due to greater concern for farmworker health), and between farm owners (via cooperatives). Our data suggests that the pandemic accelerated the transition to online markets and communication, an area of opportunity also identified in the literature (Tansuchat, Pankasemsuk, & Panmanee, 2022). Several interview participants reported a perception that consumer demand for online shopping had increased during the pandemic and that much of that demand has remained steady. As such, farmers reported continuing use of online marketplaces to sell their products, with many claiming that it has increased their sales by more than 50 percent. To make this shift, farmers reported needing to develop new technology and online marketing skills and key stakeholders, including government officials, noted new programming to support farmers in growing those skills. One farmer (large farm, multiple crops, female) reported that with these new skills, she was interested in starting her own online brand. The direct contact with consumers also led some farmers to focus more on product quality than before. For example, some farmers stated that direct contact enabled better communication between farmers and consumers, allowing consumers to provide feedback on the products and encouraging farmers to produce products that would satisfy the demands of their consumers. Conversely, some farmers and key stakeholders reported that customer demands were not always aligned with farming realities (such as being too picky about the level of ripeness or attempting to consume fruit before it was ready) posing challenges to meeting customer demands.

Hygiene restrictions also produced changes in common on-farm practices that farmers indicated impact long-lasting producer-consumer relations. For example, one farmer (large farm, multiple crops, female) explained:

> COVID had a positive impact on my farming methods because it allowed me to explore new markets and plant new fruits. [My] new practice is much more effective and the dedicated warehouse [built during the pandemic] that assists in the sanitation process and packaging will attract more customers because of [increased] fruit quality and thoroughness of sanitation.

She further explained that customers remain loyal to her business because she continues these practices today.

Finally, the more frequent use of heavy machinery, new farming practices, and new technology can require significant investment costs and lead farmers to form new relationships with each other in attempts to limit these costs (Iba & Lilavanichakul, 2024). In particular, farmers increasingly turned to cooperatives to collectively rent machinery at lower per-farm costs. Cooperatives have formed around specific crop types (such as durian and mangosteen) to enable groups of farmers to collectively negotiate a price for selling their goods to intermediaries and to share the costs of renting heavy machinery (The Nation, 2022). One farmer (small farm, multiple crops, female) stated, "Farmers cannot control the prices, but they can control the cost." Key stakeholders explained that cooperatives also enabled farmers to collectively negotiate pricing with intermediaries and lower input costs by taking advantage of economies of scale when purchasing farm inputs. According to interviewees, the provincial agricultural extension offices and Thailand Ministry of Agriculture and Cooperatives supported the formation and success of these cooperatives by encouraging small farmers to cooperate with each other and helping farmers restructure debts.

5.3. Economic systems

Economic systems are shifting as farmers turn to and continue to produce value-added products. Value-added products are those that have had their uses redefined to perform better in the market, for instance through preserving fruit, drying herbs, or processing raw produce into other goods such as ice cream or chips. Our research revealed that many farmers were pursuing value-added products in response to changes in the market and demand during the pandemic. One farmer (large farm, multiple crops, female) stated that she used her produce to make ice cream and smoothies to reach new customers and markets. Farmers in our research used fruit peels, such as durian or mangosteen, to create fertilizer and products to prevent root rot and disease. Creating value-added products also enables farmers to generate revenue throughout the year instead of only during harvest seasons (Ali et al., 2025). One farmer (medium farm, multiple crops, female), who turns bananas into value-added products, explained: "Before, [my] parents'

generation only had annual revenue but [I] changed it to become more daily, seasonal, and annual." Farmers reported that these new products have been well-received by consumers and they intend to continue producing them in the future.

Our findings demonstrate the resiliency and adaptive capacity of farmers in Eastern Thailand. The pandemic created new disruptions and accelerated some trends in labor, technology, and ideologies that led to quick adaptations that, for many farmers, improved efficiencies and productivity long-term. One farmer (medium farm, multiple crops, male) reported: "Modern farmers are developing and adapting to changes faster than the state. People know how to find ways to solve problems." The willingness to adopt new technologies and participate in networks of technology knowledge transfer (such as Smart Farmers organizations) are critical indicators of these changes and important avenues for future research. A majority of farmers in our research indicated that they will continue these practices in the future.

6. Conclusion

This paper provides insights into the complex and long-lasting impacts of the pandemic on tropical crop cultivation in Eastern Thailand. The pandemic led to temporary concerns such as labor shortages, market disruptions, and supply chain challenges. However, many farmers pursued adaptations such as utilizing new technologies and machinery, e-commerce adoption, participating in cooperatives, and modifying health and safety practices that continued after the height of pandemic disruptions. These adaptations indicate potential long-lasting changes in environmental, social, and economic systems as a greater reliance on inputs changes environments, new relationships are formed between farmers and consumers, and more growers shift to producing value-added goods. The experiences of farmers in Eastern Thailand offer valuable insights for other regions adapting to pandemic disruptions and preparing for future shocks. These findings may be informative for other agricultural communities with significant populations of smallholder farmers producing goods for domestic and international trade that similarly face market disruptions due to pandemics, epidemics, and other shocks.

Our research findings can be informative for policymakers and practitioners seeking to support farmers in the post-pandemic era and to build resiliency in the face of future shocks. In particular, our research indicates a need to support farmers' efforts to implement new technologies and efficiencies, form stronger relationships, produce value-added goods, and pursue new online markets. While some technical assistance was provided by local extension offices and the Ministry for Agriculture and Cooperatives, additional programs providing training and resources to smooth these transitions have the potential to better equip farmers to take advantage of changing demand patterns and the ongoing effects of climate change (as also suggested to extension services by Marsden et al., 2022).

Future studies might include a broader sample in terms of location, crop type, and socioeconomic status to expand comprehension of impacts throughout Thailand's agricultural system. Additionally, given the increasing relevance of climate change impacts, future research could unpack the relationship between climate change and the pandemic in changing farmer practices, as well as implications for future economic and environmental outcomes in agricultural communities. Our research found important innovations pursued by farmers that promise to provide future opportunities for improving their production and commercialization of goods and protecting against future disruptions from climate change and pandemic-related events.

CRediT authorship contribution statement

Colleen Hammelman: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Gang Chen:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization. **Nij Tontisirin:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Sutee Anantsuksomsri:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization. **Flavia Moore:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Sydney Ly:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Sonia Birla:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Zoe Archambault:** Writing – review & editing, Methodology, Investigation, Data curation. **Elaina Fleming:** Writing – review & editing, Methodology, Investigation, Data curation. **Juliette Gwanfogbe:** Writing – review & editing, Methodology, Investigation, Data curation. **Korrakot Positlimpakul:** Writing – review & editing, Methodology, Investigation. **Sirima Srisuwon:** Writing – review & editing, Methodology, Investigation.

Declaration of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Colleen Hammelman reports financial support was provided by the United States National Science Foundation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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