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COVID-19 Pandemic Effects on Sustainable Adaptations of Upstream Rubber Sector: A Case Study in Songkhla Province, Southern Thailand

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Abstract

The objectives were to study the effects of COVID-19 on stakeholders in the upstream rubber sector, and their sustainable adaptations. Quantitative and qualitative research was conducted in Songkhla Province. Stratified sampling was used to select four groups of upstream stakeholders, comprising 280 rubber households, 13 rubber cooperatives, 11 fresh latex traders, 9 local middlemen and factories/exporters, and 16 RAOT officers which included 2 central rubber market officers. The research found the following to be the most substantial effects of COVID-19 on the society, the economy, and the production technology and environment of rubber households: less community interaction, worsened mental and physical health, lower incomes, more debts, and adjustments to their consumption and expenses. The study found that 77.7% of fresh latex traders were moderately affected despite the low amount of fresh latex and its low price. Rubber traders adapted by reducing expenses, reducing risks, and keeping financial liquidity by reducing the labor wage, changing selling locations, and increasing efficiency. All factories remained in operation though they experienced labor shortages and a low supply of fresh latex leading to an inability to meet demand for concentrated latex. The upstream rubber sector adapted by increasing production at concentrated latex factories, reducing costs in the process of production (especially by lowering the labor wage), and investing more in the rubber glove industry.
Keywords: COVID-19 effect on rubber, upstream rubber adaptations, rubber sustainability adaptations

Introduction

The rapid emergence of the COVID-19 pandemic affected the entire world, infecting more than 4.9 million people and killing more than 320,000 people in 215 countries. Globally, as of 21 May 2020, there were 4,904,413 confirmed cases of COVID-19, including 323,412 deaths (WHO, 2020; Rubber Authority of Thailand (RAOT), 2020). In Thailand, from 13 January to 21 May 2020, there were 3,037 confirmed cases of COVID-19 with 56 deaths (Department of Disease Control, 2020; Tantrakarnapa and Bhopdhornangkul, 2020). A Declaration of an Emergency Situation was issued by the then prime minister, upon the approval by the Council of Ministers in its meeting on 24 March 2020, and in accordance with recommendations of the medical and public health administrators and technical personnel, under Section 5 of the Emergency Decree on Public Administration in Emergency Situations B.E. 2548 (2005) (Committee on Agriculture and Cooperatives, 2020). The declaration announced an emergency situation in all areas of the Kingdom of Thailand, from 26 March 2020 to 30 April 2020. It was issued due to the situation of the coronavirus pandemic, in accord with a law that has been in force since 2005 (Thairath online, 2020). During the research, there was neither a vaccine nor an effective medication. The government correspondingly applied measures to prevent, suppress, and delay the outbreak, as well as to create awareness and understanding among the public (Public Relations Department, 2020). It made daily assessments of the situation in response to new developments, information, and medical recommendations of various experts, taking into account the impacts on the public in terms of societal well-being, the standard of living, public healthcare resources, and to prevent unnecessary panic (United Nations Thailand, 2020; Worldometer, 2020). The government

allocated resources and put many measures in place to control the spread of COVID-19 quickly. It was a humanitarian crisis such that it was difficult to envision its impact. This crisis qualifies as a pivotal event that has created waves of changes to economic, social, environmental, and international contexts in all sectors (FAO, 2020; Schmidhuber *et al*., 2020). Due to the pandemic and the Declaration of an Emergency Situation, measures were implemented to semi-halt the economy in all areas of the Kingdom of Thailand. Travel restrictions had significant repercussions on rubber businesses and the supply chain (Charnvirakul, 2020). The livelihoods of farmers and farm workers have been adversely affected. Easing of physical distancing requirements was expected be staggered and varied from location to location (Donghyun and Pilipinas, 2020). The worldwide impact of COVID 19 measures (such as lockdowns) on the agriculture industry disrupted supply and demand in complex ways, by contributing to labor shortages in agricultural sectors in many countries, change in the composition, decreasing farm incomes, affecting the availability of key intermediate inputs for farmers, shifting consumer demand, and disrupting food supply chains (OECD, 2020). The statistical generalizations of the OECD's findings, which provide insight into the issue, need to be assessed. The objectives were to study the effects of COVID-19 on stakeholders in the upstream rubber sector, and their sustainable adaptations.

Materials and Methods

Songkhla Province was chosen as the study area due to its variety of rubber organizations in both the downstream and upstream sectors. The study period lasted from 2020 to 2022. Population: farmers, cooperatives, and entrepreneurs engaged in the primary supply chain of rubber in Songkhla Province (Figure 1). For the sample group, stratified sampling was applied for selecting the six groups of upstream stakeholders, comprising 280 farmers, 9 rubber cooperatives, 4 fresh latex collection centers, 11 fresh latex traders, 9 local middlemen and factories/exporters, and 16 RAOT officers which included 2 central rubber market officers. For data collection, 108 short semi-structured questionnaires and 40 in-depth interviews were conducted. The descriptive statistics data were analyzed using simple statistics such as frequencies, distributions, percentages, and means, presenting in table format the issues before and after the pandemic. For rubber smallholder farms, Pearson moment correlation and multiple linear regression analysis were used with the following.

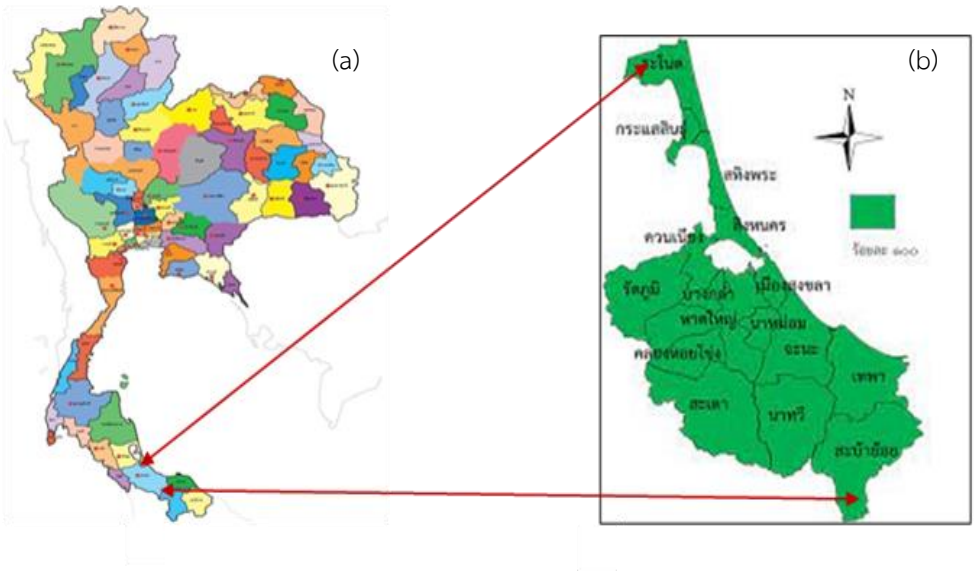

Figure 1 The study area; Thailand Map (a) and Songkhla province map (b).

Independent variables: (1) Social effects (X_1): education level, happiness with work, decreased social activity, anxiety, receipt of income support, trajectory and interaction in community, agricultural transport restrictions, household problems, modified consumption behavior, learning and self-defense, and psychological well-being (2) Economic effects (X_2): net household income level, present household debt level, present household savings level, present household expenses level, ability to settle household debts, amount of land owned, household production expenditure level, community employment level, and (3) Production technology and environmental effects (X_3): rubber technology management such as fertilizer use, weed control, plant disease and pest management, etc., household labor in rubber management and rubber harvesting, household labor in preparation and sale of rubber products, level of all chemical fertilizers used in rubber management, household labor level in management of rubber farm biodiversity, level of sale of rubber products produced by household, sources of purchased rubber products of household, sufficiency level of resources for rubber production.

Dependent variables: Livelihood adaptation strategies of rubber farmer households (Y): Changed rubber-producing techniques, increased production efficiency, reduced production costs, expanded production, increased variation in the production system, used hired labor in the agricultural sector, worked outside the agricultural sector, and modified management of household finances. Formulae of multiple linear regression: (Trammer *et al.*, 2020)

$$yi= \beta_0+\beta_1 xi_1+\beta_2 xi_2+...+\beta p xi_p+\epsilon$$

where, for i= no. observations:

yi= dependent variable

xi= independent or explanatory variables (socio-economic factors)

β_0= y-intercept (constant term)

β_p= slope coefficients for explanatory variable

ϵ= the model's error term (also known as the residuals)

Equation function model:

$$Y= a+b_1x_1=b_2x_2+....+b_nx_n+ e$$

Y= dependent variable

X_n= independent or explanatory variables (socio-economic factors)

a= y-intercept (constant term)

b= slope coefficients for explanatory variable

e= the model's error term (also known as the residuals)

Standardized equation function:

$$ZY=b_1ZX_1+b_2ZX_2+.....+b_nZX_n$$

Results

1. Effects of COVID-19 Measures on the Society of Rubber Households

1.1 Effects of COVID-19 measures on the rubber farming society

With respect to the effects of COVID-19 on the society of rubber farmers, the important issues are identified in Figure 2a-f. (1) Receipt of income support from government (Figure 2a). The study found that receiving support to pay the electricity bill affected the most survey respondents, at 67%, while support to pay the water bill affected the fewest, at 30.3%. (2) Interaction in the community (Figure 2b). The study found negative effects of social

distancing with 89.0% of respondents, and having their community closed to prevent the spread of COVID-19 with 50.5%. (3) Wellness of rubber farmers (Figure 2c). Farmers reported worse physical and mental wellness, at 73.4%. (4) Adaptation (Figure 2d). The study found that 80.7% of farmers had received adaptation training for their livelihoods. (5) Income (Figure 2e). The study found that more farmers (60.6%) used the principles of the Philosophy of Sufficiency Economy to increase their income than any other strategy, while finding work outside the community was least used, at 18.3%. (6) Community cultural activities (Figure 2f). The study found that religious activities, such as going to the temple to make merit, were the most common cultural activity, at 63.3%, while helping out in the community's free pantry was the least common, at 30.3%. The results show that the rubber farmer society was affected by the COVID-19 restrictions, consistent with Poovorawan (2021); Wongwassana (2021).

1.2 Effects of COVID-19 on the Household Economy

The effects of COVID-19 on the economy of farmer households are as follows (Figure 3 (a)-(d)). (1) Problems in the household economy (Figure 3a). The study found that 74.3% of farmers had adequate financial assets, while 45.9% sold off mortgage assets. (2) Behavior changes of rubber farmer households (lower income from outside of the agricultural sector) (Figure 3b). The study found that farmers reduced their purchases of consumer products from the community market, with 69.7% increasing their purchases from supermarkets, and 55.0% increasing their online purchases. (3) Household incomes and expenses (Figure 3c). The study found that 93.6% of farmers had decreased incomes (due to too few buyers and falling rubber prices), while 26.6% sold household assets. (4) Savings and Sufficiency Economy (Figure 3d). The study found that 92.7% of farmers saved money, thought more seriously about what they were spending money on, and that 73.4% had sought out additional sources of income, while 70.6% built strong local economic systems from scratch.

1.3 Effects of COVID-19 measures on production technology and environment

COVID-19's negative effects on production technology and environment of rubber households are illustrated in Figure 4. The study found that 74.3% of farmers spent more time and money on plantation management, e.g. fertilizer application, and pest and disease control, followed by 70.6% having higher value capital, and improved production factors (factor resources, higher selling price), 66.1% having the means to transport their rubber products, 65.1% needing to sell more products at local markets, 62.4% having more suppliers, goods, and enough production resources e.g. water, soil, technology, and information, 61.5% having more labor for production and plantation management (managing and harvesting), 60.6% having higher production output, 57.8% had managed to prepare for the production, 54.1% having increased biodiversity in their rubber plantation, and 36.7% using more chemicals (all chemicals and activities).

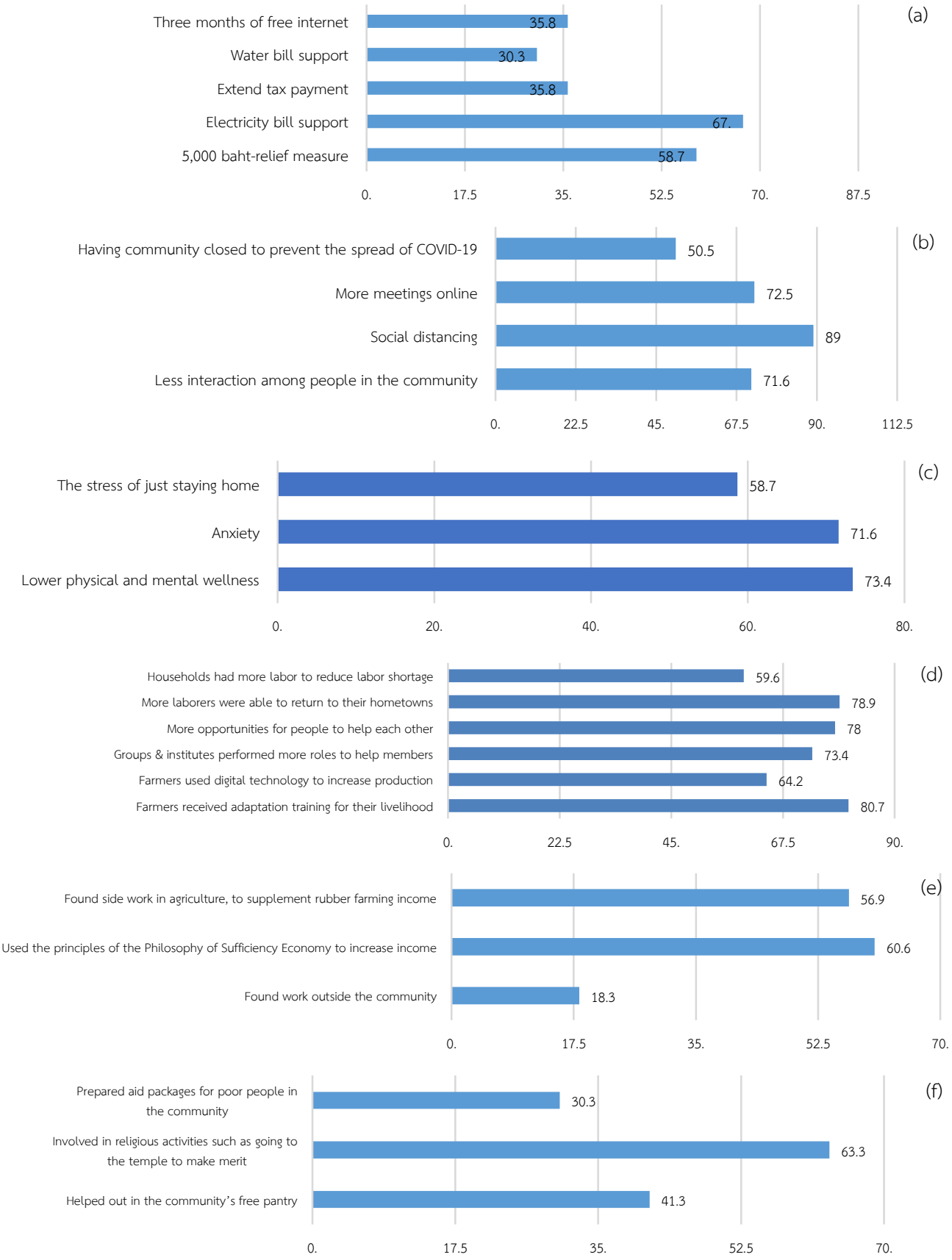

Figure 2 The effects of COVID-19 on society of rubber households. Collected from 280 samples and Negative Impact: Receiving financial support from the government (a), Negative Impact: Interaction in the community during COVID-19 (b), Negative impact: Wellness of rubber farmers (c), Positive Impact: Livelihood adaptation training (d), Positive Impact: Income support (e) and Positive Impact: Shared cultural activities in the community (f).

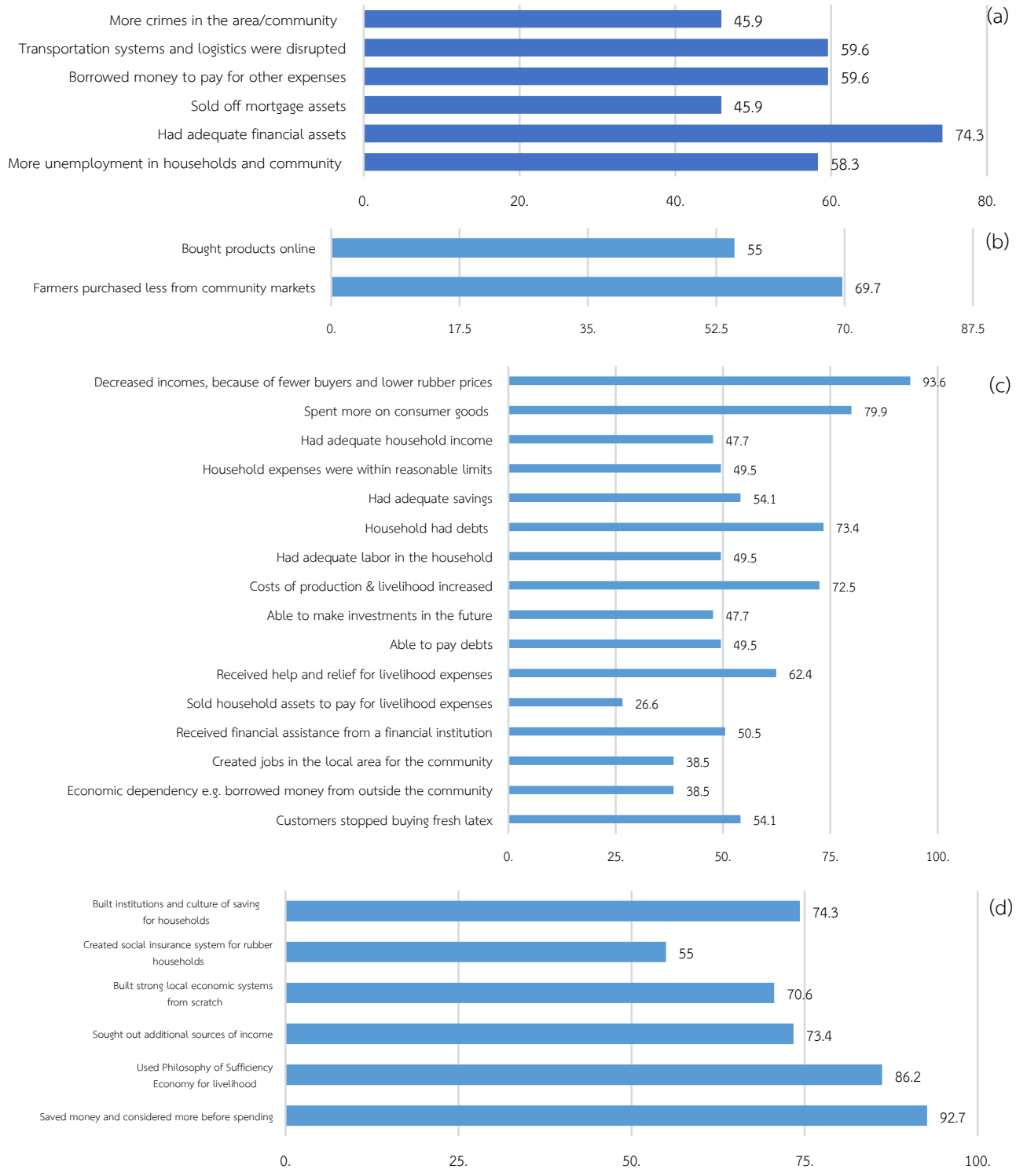

Figure 3 Effects of COVID-19 measures on the economy of rubber households collected from 280 samples, Negative impact: Problems of household economic status (a), Negative impact: Behavior changes of rubber farmer households (lower income from outside the agricultural sector) (b), Negative impact: Household income and expenses (c) and Positive impact: Savings and Sufficiency Economy (d).

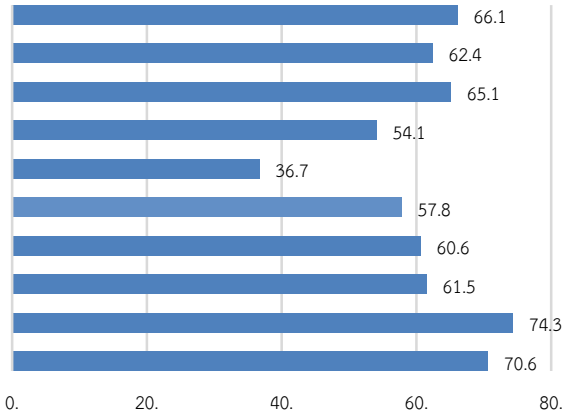

Figure 4 The effects on production technology and environment of rubber households. Footnote: Collected from 280 samples.

1.4 Adaptation strategies of rubber households

The study found the following to be the main livelihood strategy adaptations, as illustrated in Figure 5a-h. (1) Changed rubber-producing routine (Figure 5a). Sometimes stopped tapping (45.9%), decreased number of tapping days (25.7%), changed from producing fresh latex to cup lumps (11.1%). (2) Increased production efficiency (Figure 5b). Switched to growing perennial plants/vegetables that gave high yields instead of growing rubber trees (29.4%), changed to growing higher-yielding rubber breed 251 (replanting) (26.6%), used skilled tappers along with every-other-day tapping (24.8%), increased chemical fertilizer application (16.5%). (3) Reduced production costs (Figure5c). Decreased chemical fertilizer use (45.0%), used chemical fertilizer along with organic fertilizer (43.1%), changed weed control method from chemical to mechanical (38.5%), changed weed control method from mechanical to chemical (13.8%). (4) Expanded production (Figure 5d). Expanded planting areas of other economic crops (29.4%), increased number of land and aquatic animals raised, and raising area 24.0%, and expanded rubber plantation area (21.1%). Increased species variety in the production system (Figure 5e). (5) Increased the variety of plant and animal species in the production system in rubber plots (within plots) (38.9%), and increased the variety of farming production systems (among different plots), specific plants/animals (24.8%). (6) Using hired labor in the agricultural sector (Figure 5f). Found other work in the agricultural sector (planted trees and mowed lawns) (21.1%), found work tapping rubber in the village/nearby sub-district (19.3%), found work tapping rubber in a different province (9.2%). (7) Worked outside the agricultural sector (Figure 5g). Found work outside the agricultural sector (buying and selling things, food store) (30.3%), found miscellaneous work in the village (24.8%), found work in the city (and lived there) (11.9%). (8) Household financial management (Figure 5h). Reduced household expenses (78.9%), reduced unnecessary expenses (e.g. luxury goods) (77.1%), sold household assets (e.g. land, car, etc.) (19.3%).

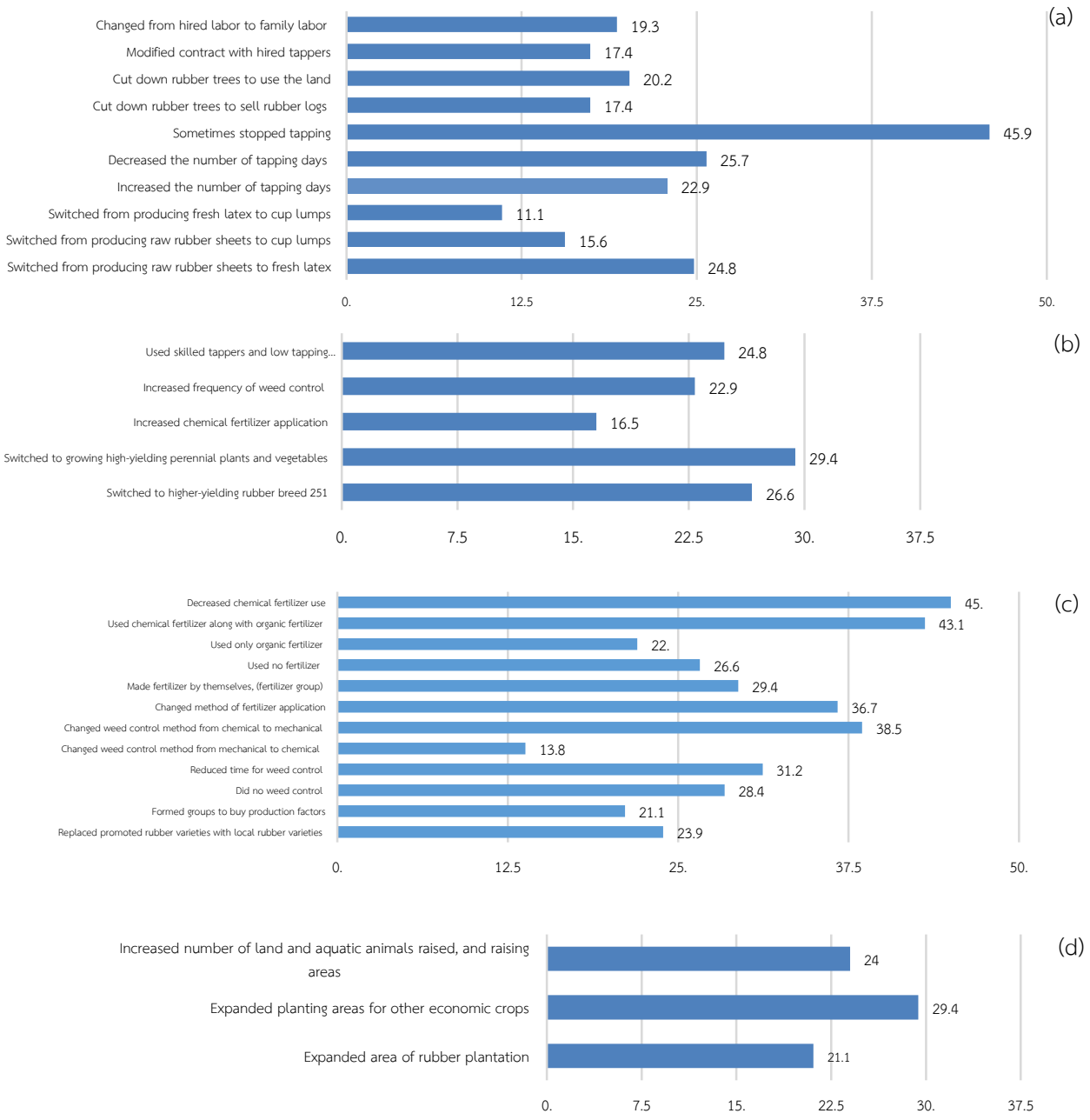

Figure 5 Effects of COVID-19 on livelihood adaptation strategies of rubber farmer households. Footnotes: Collected from 280 samples and Changed rubber producing techniques (a), Increase in production efficiency (b), Reducing production costs (c), Expand production (d), Increase varieties of production system (e), Using hired labor in the agricultural sector (f), Worked outside the agricultural sector (g) and Household financial management (h).

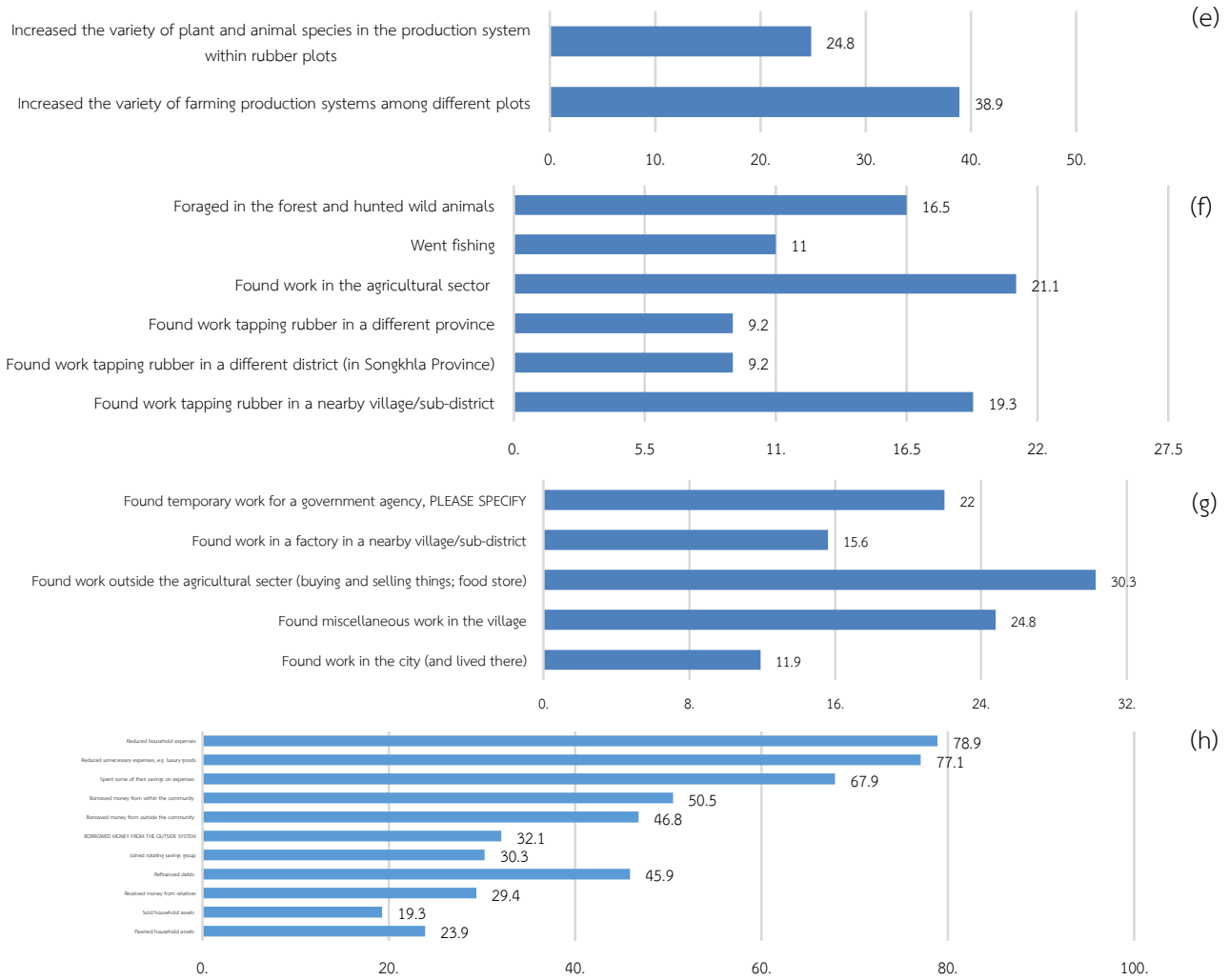

Figure 5 (Continue.) Effects of COVID-19 on livelihood adaptation strategies of rubber farmer households. Footnotes: Collected from 280 samples and Changed rubber producing techniques (a), Increase in production efficiency (b), Reducing production costs (c), Expand production (d), Increase varieties of production system (e), Using hired labor in the agricultural sector (f), Worked outside the agricultural sector (g) and Household financial management (h).

1.5 Factor correlation: effects of COVID-19 on society, economy, and production technology and environment regarding adaptation strategies of rubber households

The results show (Table 1) that the social effects variable regarding agriculture transport restrictions correlated with the adaptation strategies (R= 0.742; P= 0.01), the economic effects variable regarding net household income correlated with the adaptation strategies (R= 0.635; P= 0.01), and the production technology and environmental effects variable regarding level of biodiversity in rubber management sustainability correlated with the adaptation strategies (R= 0.667; P= 0.01).

Table 1 Factor correlation: effects of COVID-19 on society, economy, and production technology and environment regarding adaptation strategies of rubber households

Variables	The Adaptation Strategies of Rubber Smallholder Households
Social Effects	
Education level (x_1)	.894***
Happiness with work (x_2)	.419*
Decreased social activity (x_3)	667***
Anxiety (x_4)	.463**
Receipt of income support (x_5)	.961*
Trajectory and interaction in community (x_6)	.699*
Agricultural transport restrictions (X_7)	.742***
Household problems (x_8)	.347**
Modified consumption behavior (x_9)	.317*
Learning and self defense (x_{10})	.521***
Psychological well-being (x_{11})	.581**
Total	**.282***

1.6 The COVID-19 factors affecting society, economy and production technology and environment that influenced the adaptation strategies of rubber households

The results below use the equation function model and standardized function of the dependent variable factors to show that social effects (X_1), economic effects (X_2) and production technology and environmental effects (X_3) influenced adaptation strategies of rubber households (Y).

Equation function:

$$Y= 0.542+0.526X_1+0.271X_2+0.231X_3$$

Standardized equation function:

$$ZY= 0.490ZX_1+0.242ZX_2+0.205ZX_3$$

R^2= 0.669, R^2 adjust= 0.637, Std. Error of Estimation= 0.3702

F-Significant= 20.869*** Durbin-Watson= 1.552

The results of the equation function show that social effects, economic effects and production technology and environmental effects can explain adaptation strategies of rubber households at 63.7% (R^2 adjust= 0.637). Also, it was found that social effects are the most explanatory ($0.490Zx_1$).

Table 1 (Continue.) Factor correlation: effects of COVID-19 on society, economy, and production technology and environment regarding adaptation strategies of rubber households

Variables	The Adaptation Strategies of Rubber Smallholder Households
Economic Effects	
Net household income level	.635***
Present household debt level	.439**
Present household savings level	.524**
Present household expenses level	.587***
Ability to settle households debts	.487**
Amount of land owned	.446**
Household production expenditure level	.432***
Community employment level	.597***
Total	**.722****
Production Technology and Environmental Effects	
Rubber technology management such as fertilizer use, weed control, plant disease and pest management, etc.	.475**
Household labor in rubber management and rubber harvesting	.645***
Household labor in preparation and sale of rubber products	.417**
Level of all chemical fertilizers used in rubber management	.527***
Household labor level in management of rubber farm biodiversity	.667***
Level of sale of rubber products produced by household	.505***
Sources of purchased rubber products of household	.457**
Sufficiency level of resources for rubber production	.397**
Total	**.618****

2. Effects of COVID-19 Measures on Fresh Latex Traders

The effects of COVID-19 measures on the adaptations of fresh latex traders during March-May 2020 may be identified as follows (Figure 6a-h). (1) Effects on general business operations of fresh latex traders (Figure 6a). The study found that 77.7% of farmers were moderately negatively affected and that 5.6% were severely affected. The three most common effects were the falling price of fresh latex, a smaller amount of fresh latex produced, and a decreased number of farmers who came to sell fresh latex. The results show that 5.6% of fresh latex traders were positively affected, and 11.1% were unaffected. (2) Problems with business operations during COVID-19 (Figure 6b). The following problems were reported: falling price of fresh latex (25.8%), a reduced amount of fresh latex was produced (19.7%), a decreased number of farmers came to sell fresh latex (16.7%), unstable rubber market (12.1%), less cash flow, and more restrictions on transporting fresh latex to trading points (6.1%), decreased purchases of fresh latex by factories (3.0%), closed factories, reduced working hours of employees, and closing of the central rubber market (1.5%). (3) The price of fresh latex during COVID-19 (Figure 6c). The study found that the fresh latex price dropped 72.0% from March to May 2020, an average of 21.33% compared with 28.0% during the same months in 2019, when there was no change in the fresh latex price. (4) The amount of fresh latex bought during COVID-19 (Figure 6d). Some 83.0% of businesses bought less fresh latex; an average of 29.40% bought less compared with the same time in 2019, and 17.0% bought the same amount as in 2019. (5) Businesses' incomes during COVID-19 (Figure 6e). Incomes fell from March to May 2020 an average of 39.58% for 72.0% of businesses compared with the same time in 2019, while 28.0% had no change in income. (6) The problem of financial liquidity during COVID-19 (Figure 6f). Most fresh latex traders had no financial liquidity problems (83.0%), while 17.0% did have problems. (7) Business closures during COVID-19 (Figure 6g). Some 11.0% of businesses closed, whereas 89.0% did not. (8) Labor problems during COVID-19 (Figure 6h). Serious labor problems were reported by 72.2%, while milder problems were reported by 11.1%. Examples include the prohibition on travel to other provinces or countries, the unwillingness to go to work due to the fear of getting sick, and the stay-at-home order.

3. Factories and Middlemen Stopped Buying Fresh Latex Due to COVID-19 Measures

Due to COVID-19 and the measures implemented to prevent its spread, factories and middlemen stopped buying fresh latex, as follows (Figure 7a-b). (1) Factories and middlemen stopped buying fresh latex (Figure 7a). Because of closed export borders and the risk from export markets (11.0%), no effect; did not stop buying fresh latex (89.0%). (2) Measures by fresh latex traders to handle the COVID-19 situation (Figure 7b). Decreased the wage paid to laborers (24.1%), decreased operation expenses (13.8%), found new suppliers, increased efficiency of the production process, decreased working hours, and reduced labor (10.3%), reduced production costs, secured more bank loans, stopped trading fresh latex, changed production formats (6.9%), and changed formats for selling products (5.6%).

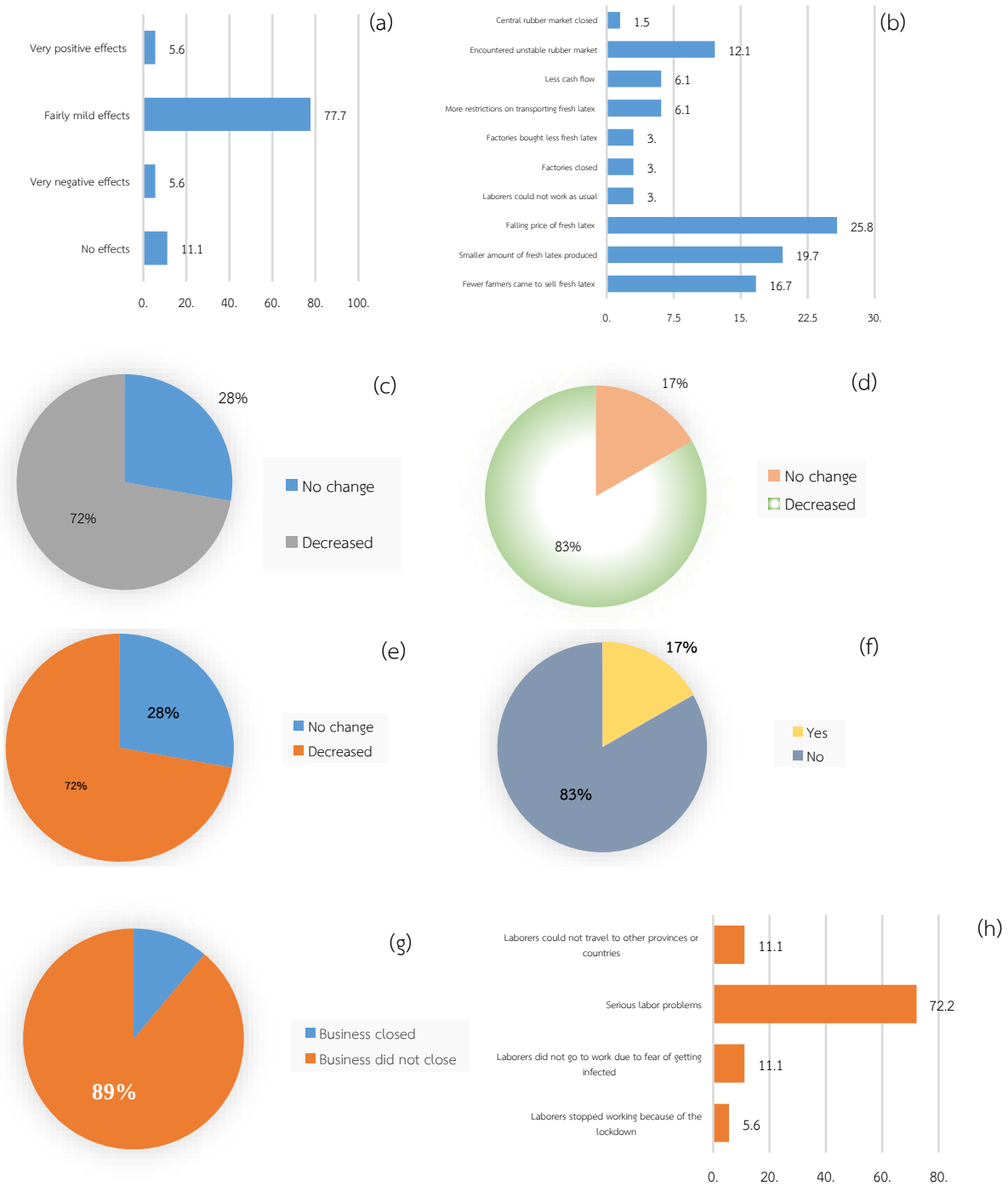

Figure 6 Effects of COVID-19 on the adaptations of fresh latex traders.
Footnotes**:** Effects on general operations of fresh latex traders (a), Problems of business operations during COVID-19 (b), Prices of fresh latex during COVID-19 (c), Amount of fresh latex bought during COVID-19 (d), Business revenues during COVID-19 (e), Problems of financial liquidity during COVID-19 (f), Business closures during COVID-19 (g) and Labor problems during COVID-19 (h).

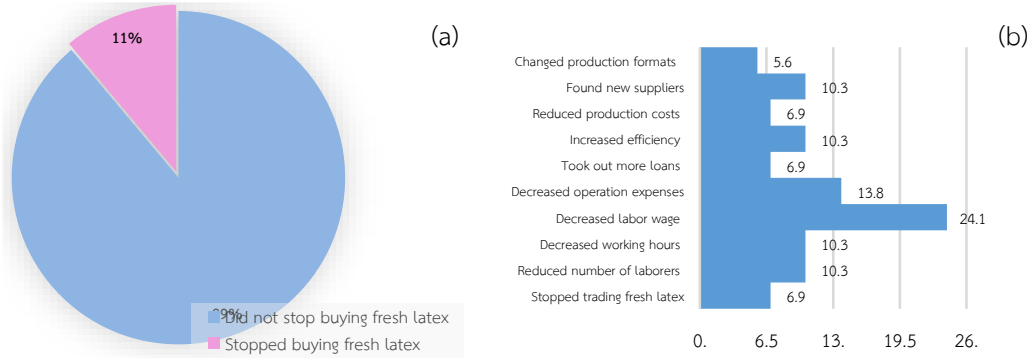

Figure 7 Effects of COVID-19 on factories and middlemen: they stopped buying fresh latex.
Footnotes: Some factories and middlemen stopped buying fresh latex (a) and Fresh latex traders' measures to handle the pandemic (b).

4. Effects of COVID-19 Measures on Rubber Cooperatives and Fresh Latex Collection Centers

4.1 The effects of COVID-19 measures on a particular rubber cooperative

The effects of COVID-19 measures on a particular rubber cooperative are as follows. (1) have a few negative effects. Fewer farmers came to sell fresh latex, invariably selling a smaller amount. As sustainable adaptations, the cooperative reduced its pay to its committee, and gave each farmer a 5 kg sack of rice during COVID-19. (2) The cooperative produced a little bit less fresh latex than normal. As sustainable adaptations, while an imposed curfew was in place, the cooperative issued a letter from the head of the village permitting farmers to leave the village to tap rubber, and on two occasions, gave farmers a 5 kg sack of rice. (3)

As sustainable adaptations, the cooperative reduced its pay to its committee, and gave each farmer a 5 kg sack of rice during COVID-19. The cooperative's sustainable adaptions were to sell fresh latex instead of smoked rubber sheets, reduce labor from 3 workers to 1 worker, decrease the labor wage by 50% from 600 baht/day to 300 baht/day, decrease the pay for fresh latex transport from 200 baht/trip to 0.10 baht/kg/trip. (4) Fewer farmers came to sell fresh latex and the cooperative bought 50% less fresh latex than during the same period of the previous year. Their sustainable adaptations were to reduce the number of employees from three to two, alternate working days for an average at 15 days/month/employee, reduce their own working hours, and work half a month for half the usual salary. (5) The price and amount of fresh latex each fell 30% compared with the same period of the previous year. They made the following sustainable adaptations: allowances were decreased for the committee members and for meetings and sometimes not paid at all, efficiency of the production process was increased, production costs were decreased, cheap firewood was used, and employees and farmers were ordered to wear masks. (6) Foreign laborers had to stop producing smoked rubber sheets because they could not go back to their countries to renew their work permits. The cooperative's sustainable adaptation was to reduce wages by 1,500 baht/month because another rubber cooperative reduced wages by 50% compared with the same period of the previous year. (7) The price of smoked rubber sheets fell, fewer farmers came to sell fresh latex, farmers were afraid of leaving their houses, farmers were reluctant tap rubber, and the cooperative bought less fresh latex. As a sustainable adaptation, the cooperative did not pay wages to laborers during the period it did not buy fresh latex. Another rubber cooperative sold fresh latex by selling to a larger fresh latex collecting center, and assisted members by letting them forego debts and loans for the months of April and May 2020. (8) The market prices of fresh latex and smoked rubber sheets fluctuated, thus the cooperative decreased by 30% the amount of fresh latex it bought, and the price it paid. As a sustainable adaptation, it gave free sacks of rice to Laotian workers who produced smoked rubber sheets when the cooperative began to sell fresh latex again. Currently, three of four Laotian workers are working; one could not come back from Laos. (9) The cooperative reduced its number of customers because the owners of the plantations hired foreign workers. Some foreign laborers went back to their countries because of COVID-19 and could not return to Thailand. As sustainable adaptations, the cooperative cooperated with factories by selling fresh latex during COVID-19, paid laborers 26% of profits, and loaned to spend

among members.

4.2 The Effects of COVID-19 Measures on Fresh Latex Collection Centers

The effects of COVID-19 measures on fresh latex collection centers are as follows. (1) Businesses had fewer customers who came to buy fresh latex because Myanmarese customers could not come to Thailand. As a sustainable adaptation, the cooperative reduced its working hours by an hour and a half. (2) Fresh latex spoiled because factories stopped buying it, thus its price fell. As sustainable adaptations, strict cleanliness practices to prevent spoilage of fresh latex were required of everyone who came to sell fresh latex, the number of meetings was reduced, and Zoom was used for online meetings among outside working units. (3) The number of customers diminished thus the amount of fresh latex production also diminished, to 50%. The sustainable adaptations were to leave fresh latex to stand for two or three nights before selling, and to reduce the labor wage from 200 baht/day to 100 baht/day, from March to June 2020. (4) The price of fresh latex fell at the beginning of COVID-19. Farmers laborers did not go to work due to the fear of getting infected. As sustainable adaptations, the cooperative prioritized sanitation, and found new sources of fresh latex.

Discussion

1. The sustainable adaptations of the upstream rubber sector

1.1 The sustainable adaptations of rubber households

From the results of this study, a snapshot of some major effects of COVID-19 on farmers is illustrated in Figure 8. (1) Rubber plantation labor. For small-size rubber households, the pandemic measures had no effect on labor type. Labor was unchanged at an average of 2.0 workers/household, specifically the husband and wife. There were still enough local tappers, except for those farmers with large rubber plantations who hired foreign workers. Border closures at the end of April 2020 forced foreign workers go back to their countries, and prohibited them from coming back to work in Thailand. Owners of rubber plantations resolved the problem by hiring local labor. Some rubber plantations stopped tapping rubber. The proportion of large rubber plantations was quite low in this study area. Furthermore, some households had more labor because of layoffs due to temporary closures of businesses in the tourism and industry sectors. A small number of laborers moved back to the agricultural sector in the community, ready to return to their jobs once economic restrictions would be lifted. (2) Technology in rubber plantations and livelihoods. The pandemic measures had no effect on technology in the rubber plantations, but did accelerate the rate of digitalization of off-farm aspects of their livelihoods, and their online lives more generally. This means that some farmers used various online markets, and the farmers' own digital markets to sell their agricultural products. During March-May 2020, farmers consumed more digital media and used digital channels as their main means of communication to reduce face-to-face meeting among neighbors in their communities. (3) Production and rubber plantation management. All farmers still sold their products at the buying points, unchanged from before COVID-19. One reason for this might be the government's measure that provided facilities for farmers to tap rubber and transport products to the buying points as usual. Furthermore, farmers had more time for work on their rubber plantations and other agricultural activities due to decreased social activities. For example, farmers spent more time on weed control, applying fertilizer, growing vegetables and fruits, and raising livestock. (4) Selling rubber products. All farmers were able to transport products and sell them at the fresh latex buying points with no let up. This means that all products could be sold at rubber markets as usual. However, news of rubber factory closures or interruptions in buying fresh latex might have created anxiety and panic among farmers, and some buyers might have temporarily delayed buying products. At the end of March 2020, rubber trading was being conducted as usual. Most farmers had adopted health safety measures recommended by the government. For example, farmers wore masks while coming to sell fresh latex at the buying points. (5) Falling rubber prices and uncertainty. From the beginning of January into February 2020, the price of fresh latex had averaged 41.0 baht/kg before falling to 35.0 baht/kg at the end of March, a 14.6%/month price decrease. It rose to 36.0 baht/kg during April then up to 42.0 baht/kg in May, the pre-COVID-19 level. The major factors leading to the falling rubber price

were demand shock and decreasing rubber supply because tapping season had closed. The need for more rubber gloves for health care drove the rubber price up. After COVID-19 was under control, though the price of fresh latex had recovered to an average price of 50.0 baht/kg, it was still lower than in 2019. In the same period, the price of raw rubber sheets at local markets fell and did not recover until July 2020. From the beginning of January into February 2020, the price of raw rubber sheets was an average of 41.6 baht/kg before falling to its lowest price at 35.2 baht/kg in April 2020, a drop of 15.4%/month. Also, the price maintained an average of 35.8 baht/kg during May and June, when there were signs that the price of raw rubber sheets would recover. The major influence was demand shock in the vehicle industry, such that there were delays or stoppages in vehicle production all over the world. Vehicle sales plummeted more than 80.0%, which led to decreasing need for smoked rubber sheets used in the tire industry. Famers who had been used to selling raw rubber turned to selling fresh latex.

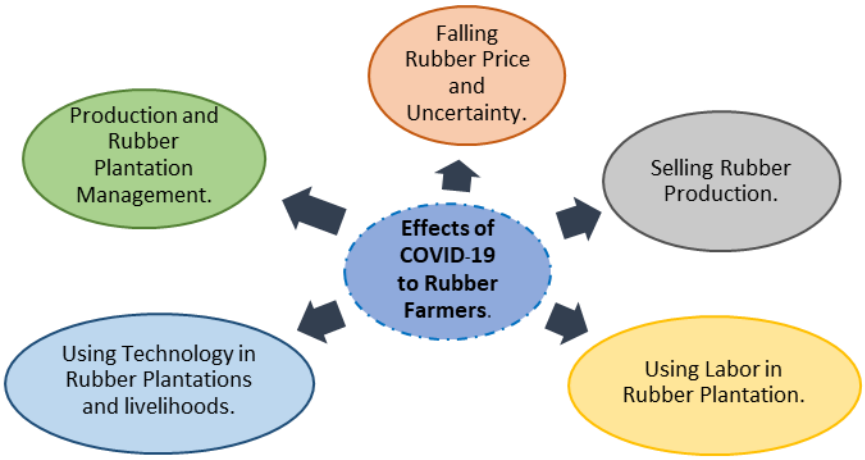

Figure 8 Snapshot of some major effects of COVID-19 on farmers' household.

1.2 The sustainable adaptations of rubber traders (sub-traders, fresh latex traders, farmer groups, and RAOT cooperatives) and factories

The results of this study are as shown in Figure 9. (1) Shortage of foreign labor in smoked rubber sheet factories. All RAOT cooperatives were impacted by the labor shortage. Because of the pandemic, foreign laborers went back to their countries and could not return to work, contributing to? / causing? closures of some smoked rubber sheet factories until today. As a temporary solution, all RAOT cooperatives chose to stop producing smoked rubber sheets. Cooperatives employing foreign labor adapted by having them help trade fresh latex. However, wages and livelihood expenses were reduced due to austerity measures agreed upon by RAOT cooperatives. Sub-traders who hired local labor had no labor shortages. Due to the lower amount of fresh latex, some sub-traders had to reduce labor wages. (2) Less fresh latex production resulted in lowered incomes and liquidity. From March to May 2020, all rubber traders had 30-50% less fresh latex compared with March to May 2019. This was due to the closure of the tapping season, having no hired tapping labor, and the low number of member farmers who came to sell fresh latex because they canceled their memberships in RAOT cooperatives. In some ways, these resulted from COVID-19 measures. However, most rubber plantations returned to tapping in June 2020, which helped relieve the aforementioned problems. (3) Marketing risks and rubber price fluctuations. On the whole, the fresh latex price was 30.0% lower compared with the same period in 2019. The pandemic obviously led to price fluctuations and marketing risks in March and April 2020. The price of fresh latex had been falling steadily from 41.0 baht/kg to its lowest at 35.0 baht/kg before recovering in May 2020. Meanwhile, some fresh latex companies ceased buying during certain periods. All rubber traders recognized the high risks associated with the demand shock. Before COVID-19, they were more accepting of marketing risks. Paying close attention to developments, and switching to buying from concentrated latex factories became the major marketing strategy. (4) Focus shifted to

business adaptations to reduce expenses and maintain liquidity. Most rubber traders had changed their business management methods by focusing on reducing expenses, reducing risk, and maintaining liquidity. This was because cooperative members had less ability to pay back loans, canceled their cooperative memberships, withdrew their savings from the cooperatives, had less fresh latex, and had lower incomes. These made all rubber traders reduce all expenses (e.g. labor wages, operation costs, transportation costs, allowances, etc.) and then focus on liquidity to move business operations forward.

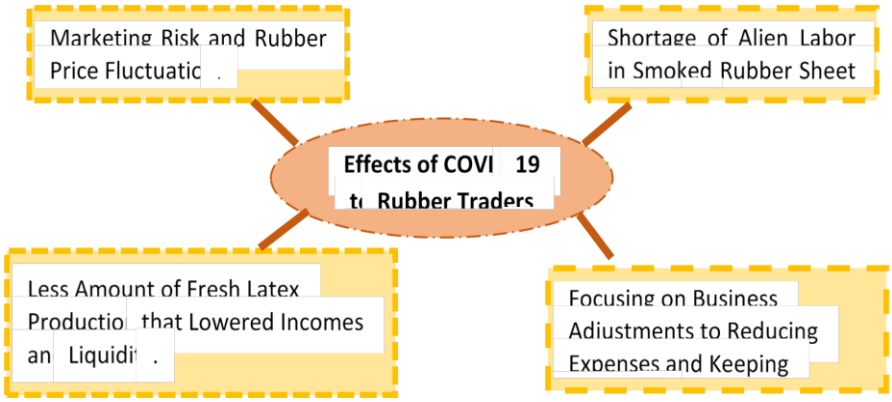

Figure 9 Snapshot of some major effects of COVID-19 on rubber traders (sub-traders, fresh latex traders, farmer groups, and RAOT cooperatives) and their adaptations.

Conclusions

The strongest of the negative impacts of COVID-19 measures on society, were found to be the receipt of support for the cost of the electricity bill, at 67.0%, social distancing, at 89%, and lower physical and mental wellness, at 73.4%. The positive impacts of COVID-19 measures on society were that farmers had more income as a result of applying the principles of Philosophy of Sufficiency Economy, at 60.6%, and that farmers were involved in religious activities such as going to the temple to make merit, at 63.3%. The negative effects of COVID-19 measures on the economy were that farmers had adequate financial assets, at 74.3%, transportation systems and logistics were disrupted, more debt was created to pay for more expenses, at 59.6% each, farmers bought fewer products from community markets and started to buy more products from supermarkets, at 69.7%, farmers had decreased incomes, at 93.6%, farmers had heavier household debts, at 72.5%, and farmers had higher production costs, at 62.4%. As for the positive effects of COVID-19 on the economy, 92.7% of farmers could save money, 86.2% thought more about what they were spending money on, and 86.2% used Philosophy of Sufficiency Economy in their livelihoods. Regarding the effects of COVID-19 on production technology and environment, the study found that 74.3% of farmers practiced more plantation management e.g. fertilizer application, and pest and disease control. The study also looked at the correlation between the effects of COVID-19 measures on society, the economy, and production technology and environment regarding adaptation strategies of rubber households. It was found that the social effects variable regarding agriculture transport restrictions correlated with the adaptation strategies of rubber households (R= 0.742; P= 0.01); the economic effects variable regarding net household income correlated with the adaptation strategies of rubber households (R= 0.635; P= 0.01); and the production technology and environmental effects regarding level of biodiversity for rubber management sustainability of the household correlated with the adaptation strategies of rubber households (R= 0.667; P= 0.01). Regarding the effects on society, economy, and production technology and environment from COVID-19 measures on the adaptation strategies of rubber households, it was found that social effects, economic effects, and production technology and environmental effects could explain the adaptation strategies at 63.7% (R^2 adjust= 0.637) and that social effects were the most explanatory ($0.490Zx_1$).

The effects of COVID-19 measures on 77.7% of fresh latex traders were relatively mild. More problematically, 19.7% of traders reported that the measures led to diminished fresh latex production, 72.0%

reported lower fresh latex prices, 83.0% reported buying less fresh latex, 72.0% reported declining revenues, 83.0% reported having adequate financial liquidity, and 72.2% reported having severe labor problems. For the effects of COVID-19 measures on factories' and middlemen's purchases of fresh latex, 89.0% were unaffected, 24.1% decreased the wage they paid, and 13.8% decreased operation expenses.

The study found that all rubber cooperatives experienced negative effects. Fewer farmers came to sell, farmers were reluctant to tap rubber due to the uncertainty of being able to sell the fresh latex, and decreased earnings from transporting fresh latex. Fresh latex collection centers also faced negative effects. Fewer customers came to buy fresh latex because Myanmarese customers could not come to Thailand, leading to a lower price of fresh latex, and fresh latex spoiled because factories quit buying fresh latex.

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